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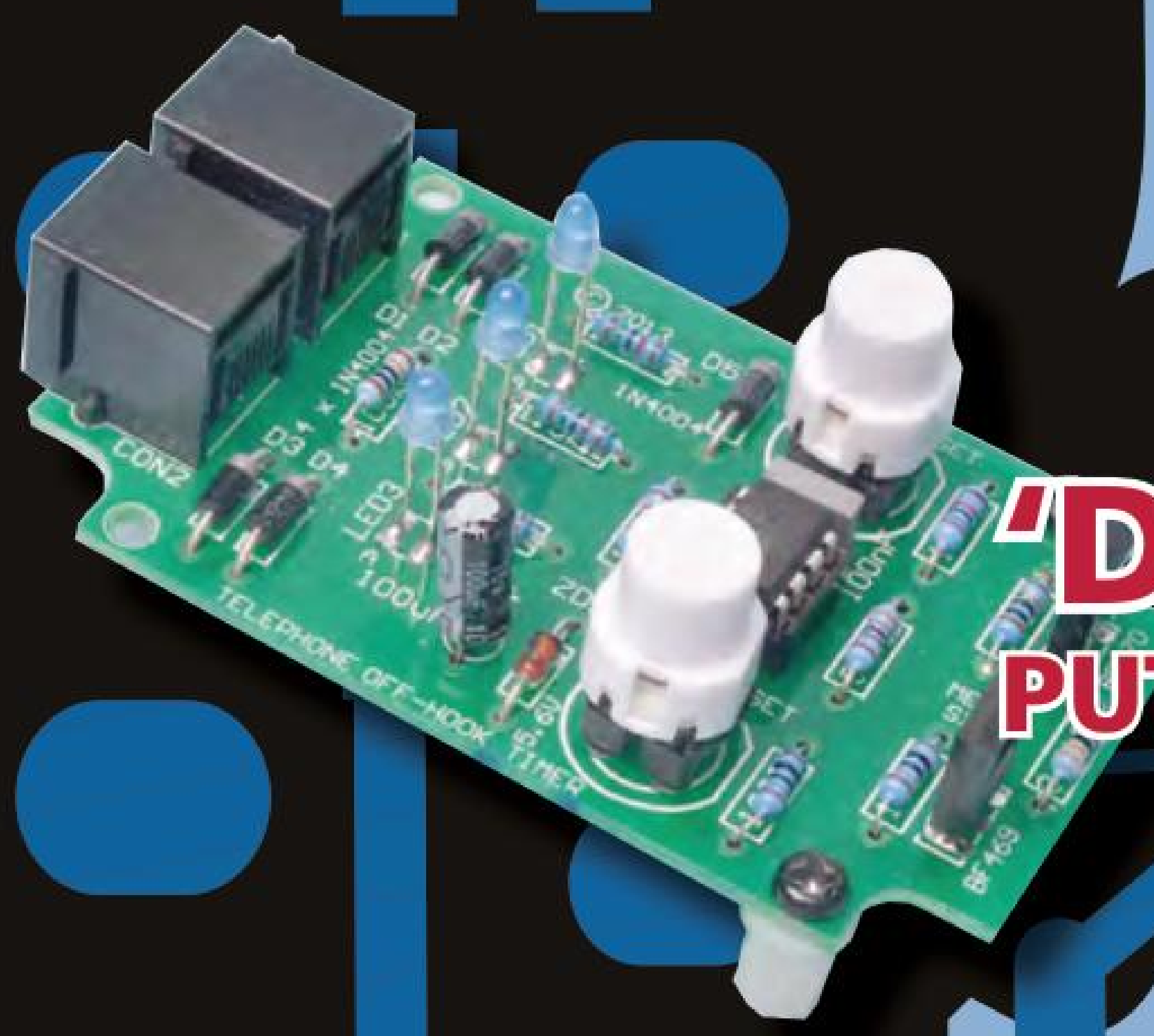

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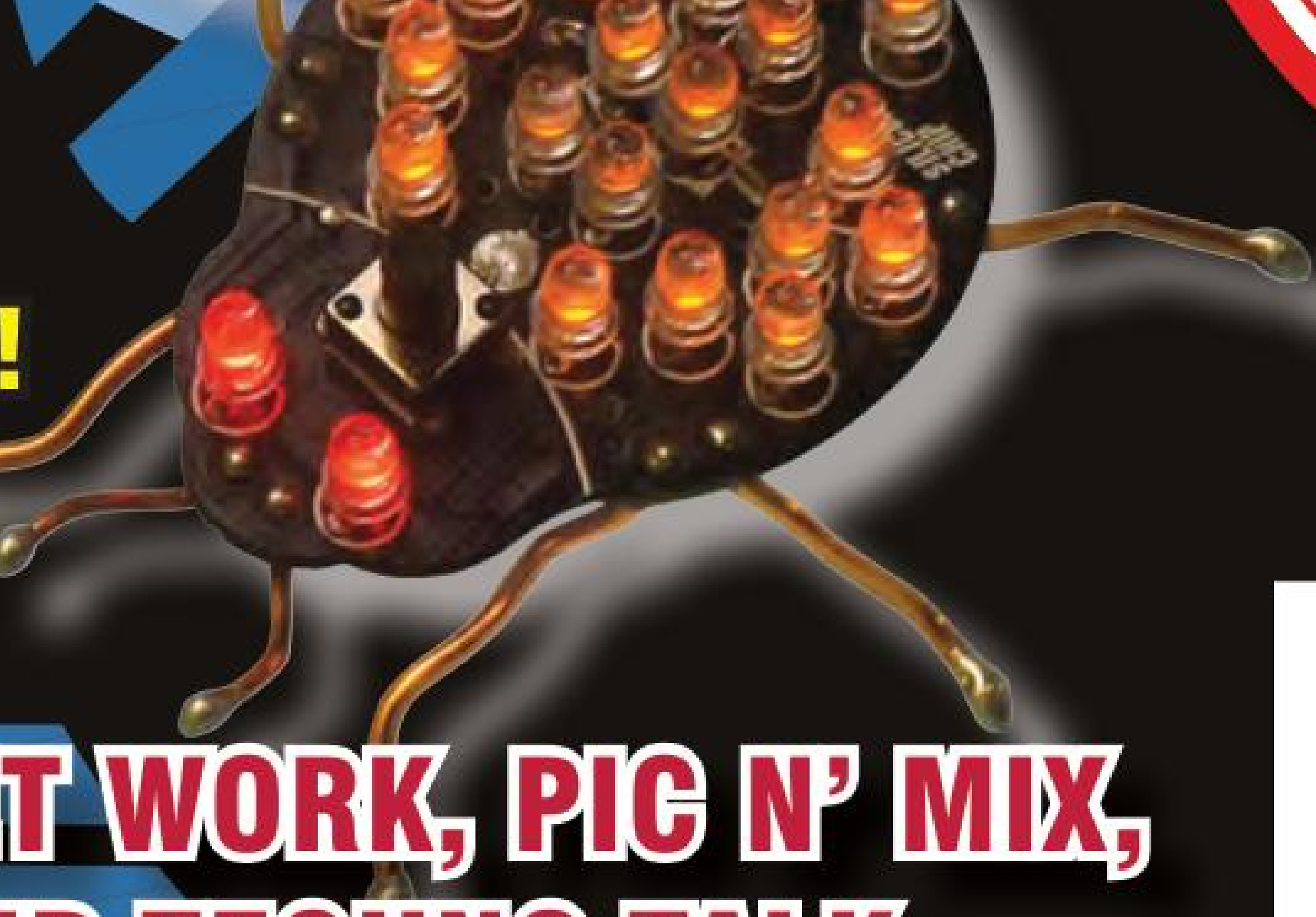

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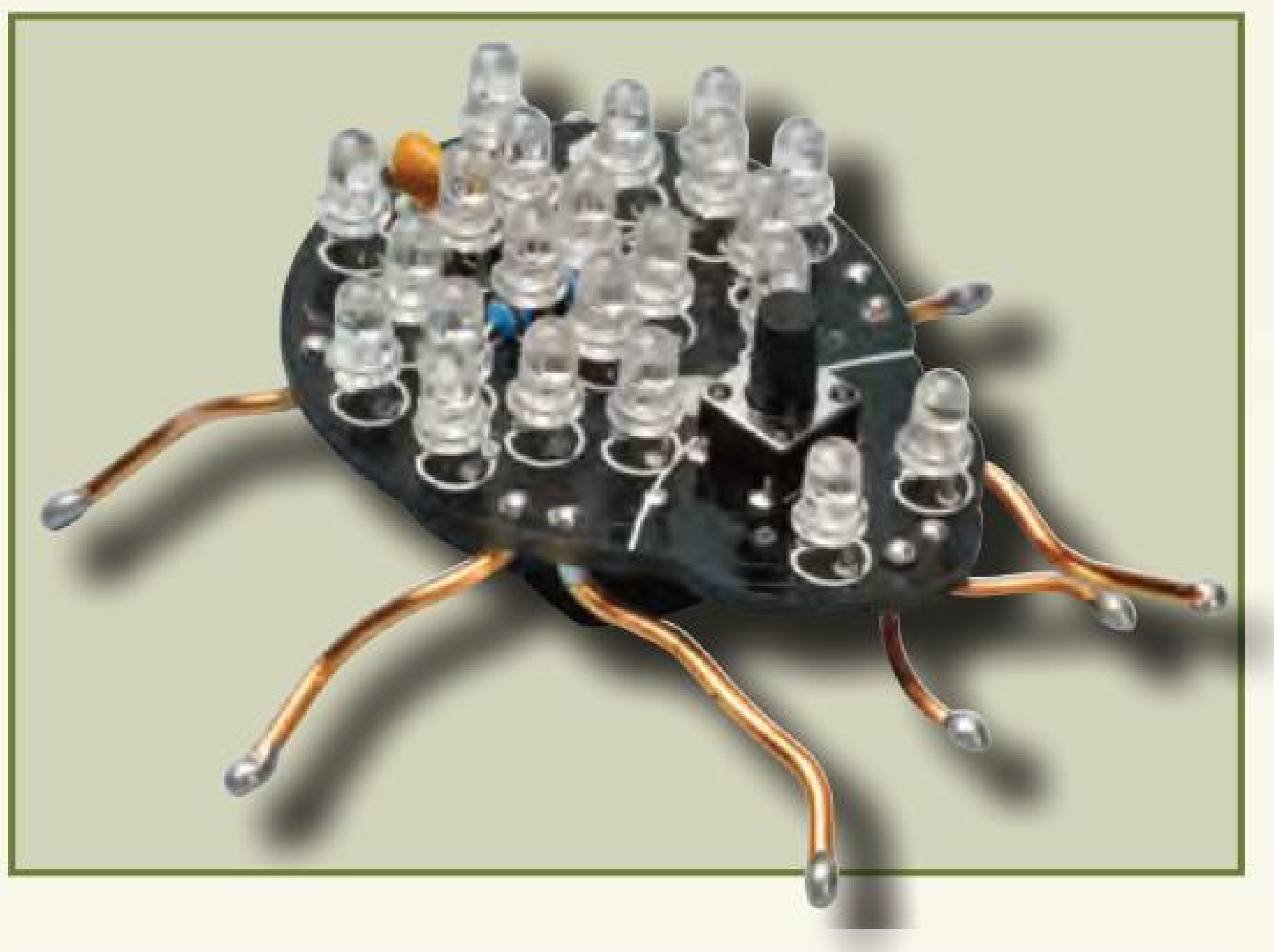

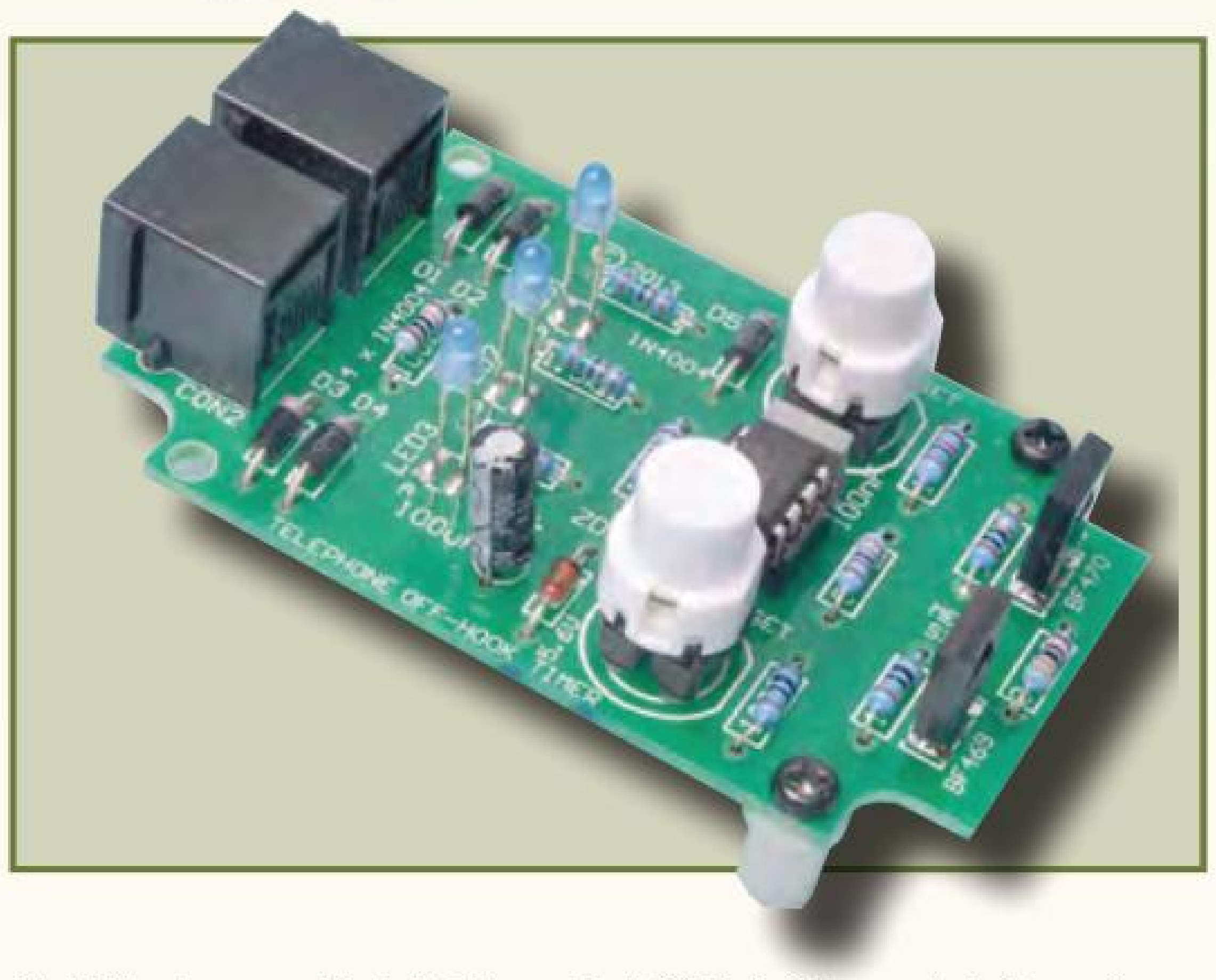

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Kit Order Code: 3179KT - ***£17.95***
Assembled Order Code: AS3179 - ***£24.95***

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Kit Order Code: 3158KT - ***£24.95***
Assembled Order Code: AS3158 - ***£34.95***

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Kit Order Code: 3166v2KT - ***£23.95***
Assembled Order Code: AS3166v2 - ***£33.95***

DC Motor Speed Controller (100V, 7.5A)

Control the speed of almost any common DC motor rated up to 100V, 7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
Kit Order Code: 3067KT - ***£19.95***
Assembled Order Code: AS3067 - ***£27.95***

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

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Kit Order Code: 3108KT - ***£74.95***
Assembled Order Code: AS3108 - ***£89.95***

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
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Additional DS1820 Sensors - ***£4.95 each***

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Kit Order Code: 8157KT - ***£49.95***
Assembled Order Code: AS8157 - ***£54.95***

4-Ch DTMF Telephone Relay Switcher

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Assembled Order Code: AS3140 - ***£94.95***

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PROJECTS • High-energy Electronic Ignition System – Part 1 • Mobile Phone Loud Ringer! • 2.5GHz 12-Digit Frequency Counter With Add-on GPS Accuracy – Part 2

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APR '14

PROJECTS • Jacobs Ladder • Deluxe GPS 1pps Timebase For Frequency Counters • Capacitor Discharge Unit For Twin-Coil Points Motors

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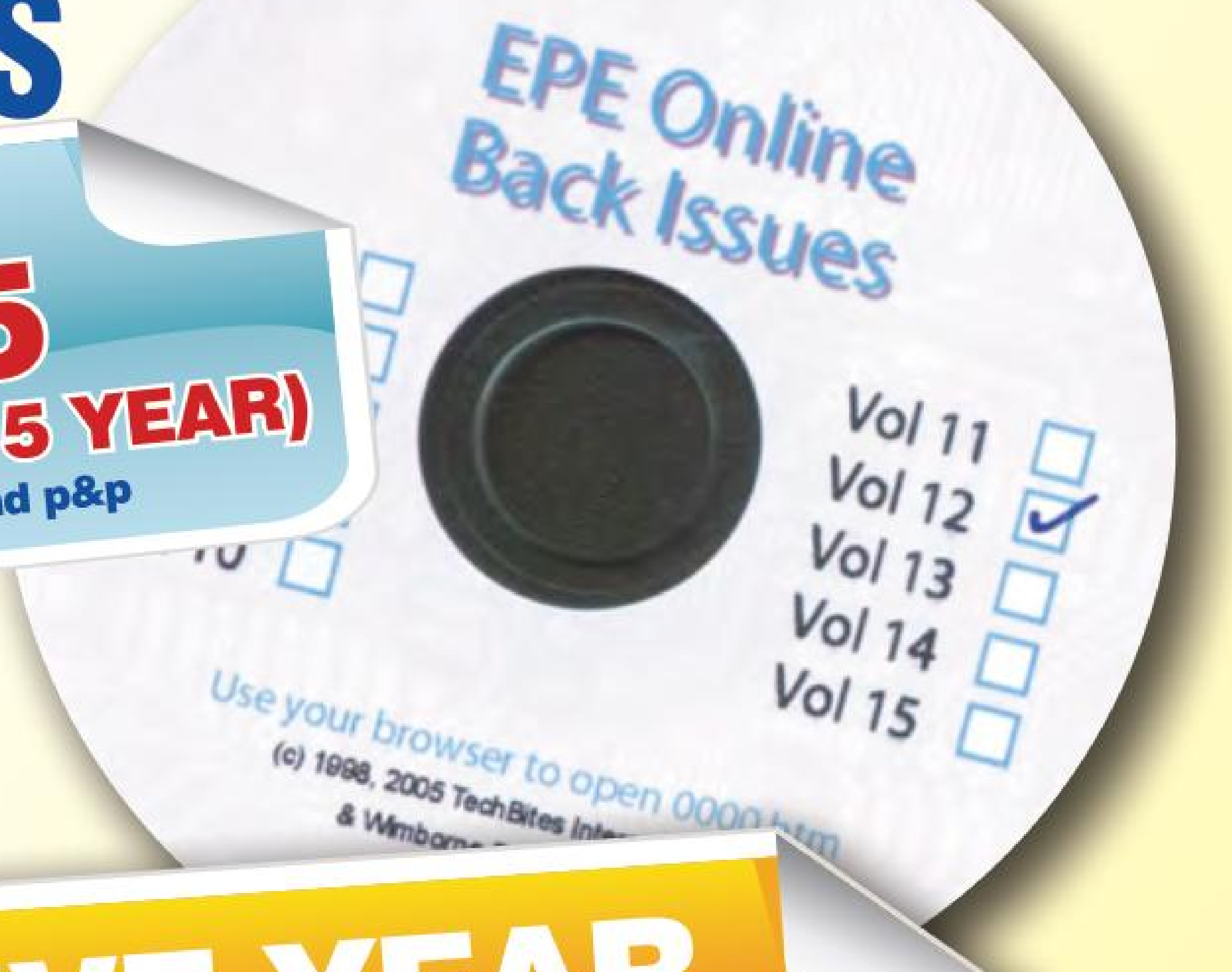
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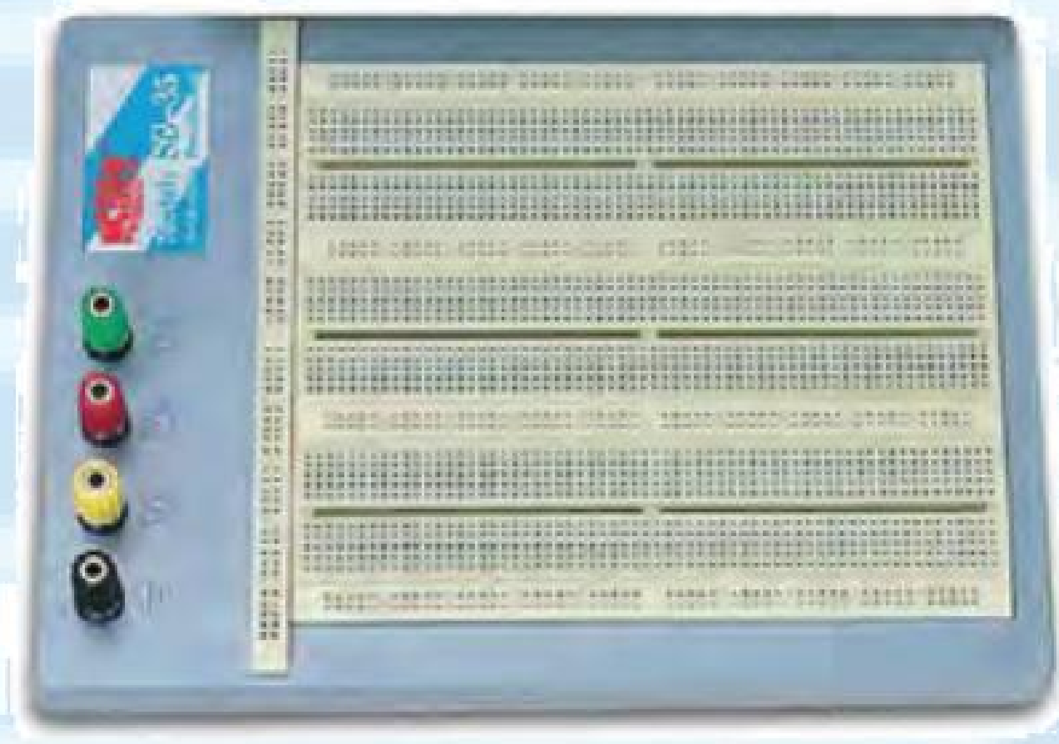

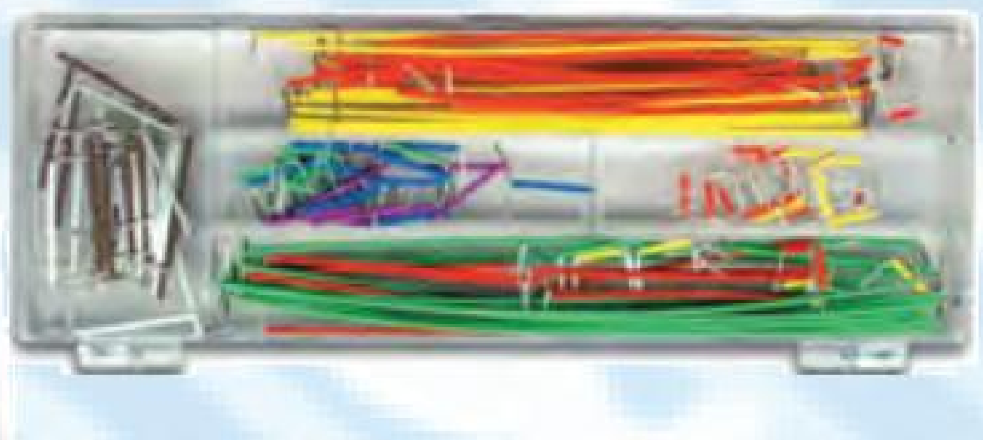

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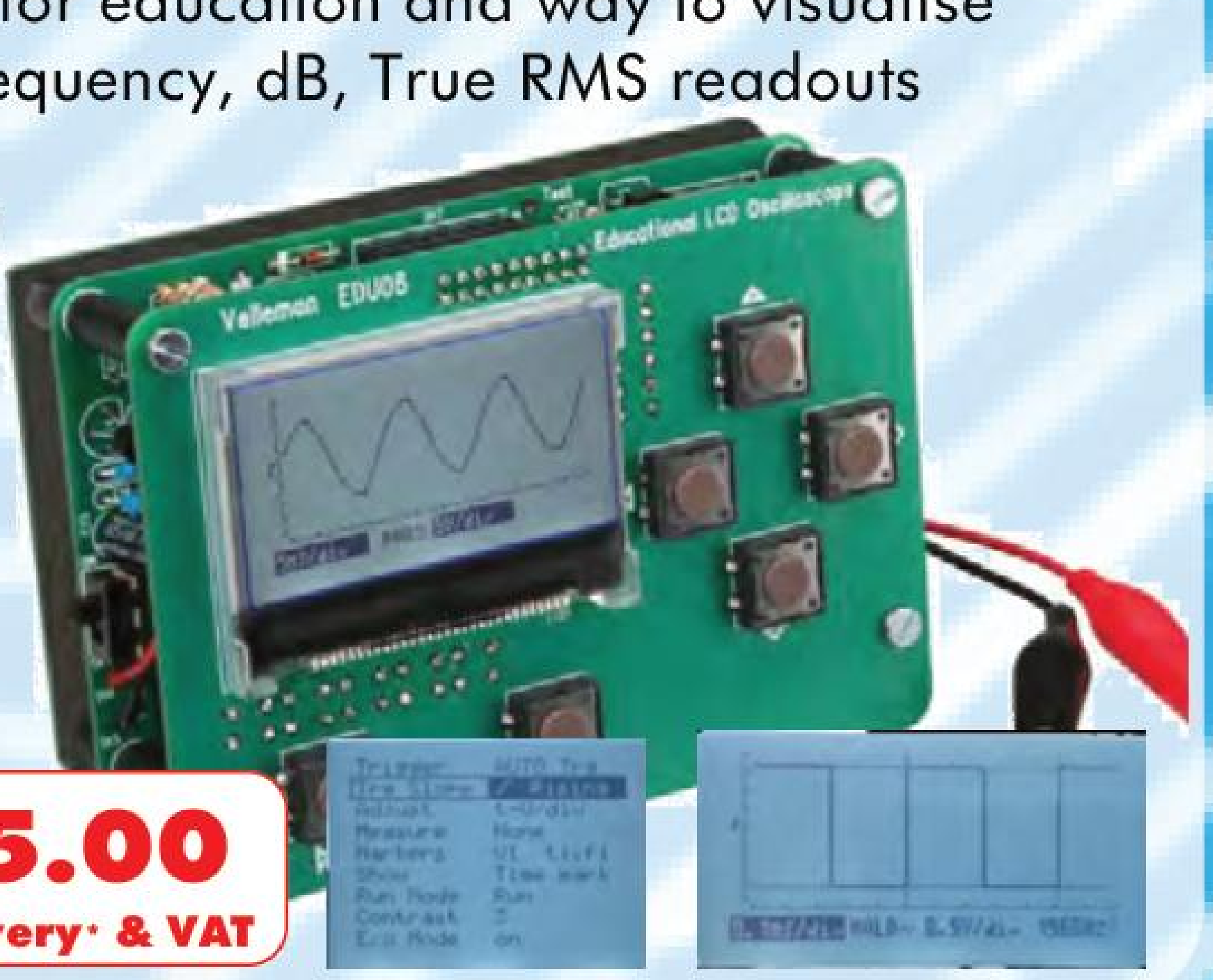
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EVERYDAY PRACTICAL ELECTRONICS

Building a classic

In the age of DAB and Internet radio you may have thought that AM radio had gone the way of the dodo and fax machine, but in fact it is very much alive, as the long list of UK AM stations mentioned in this month's lead project reveals.

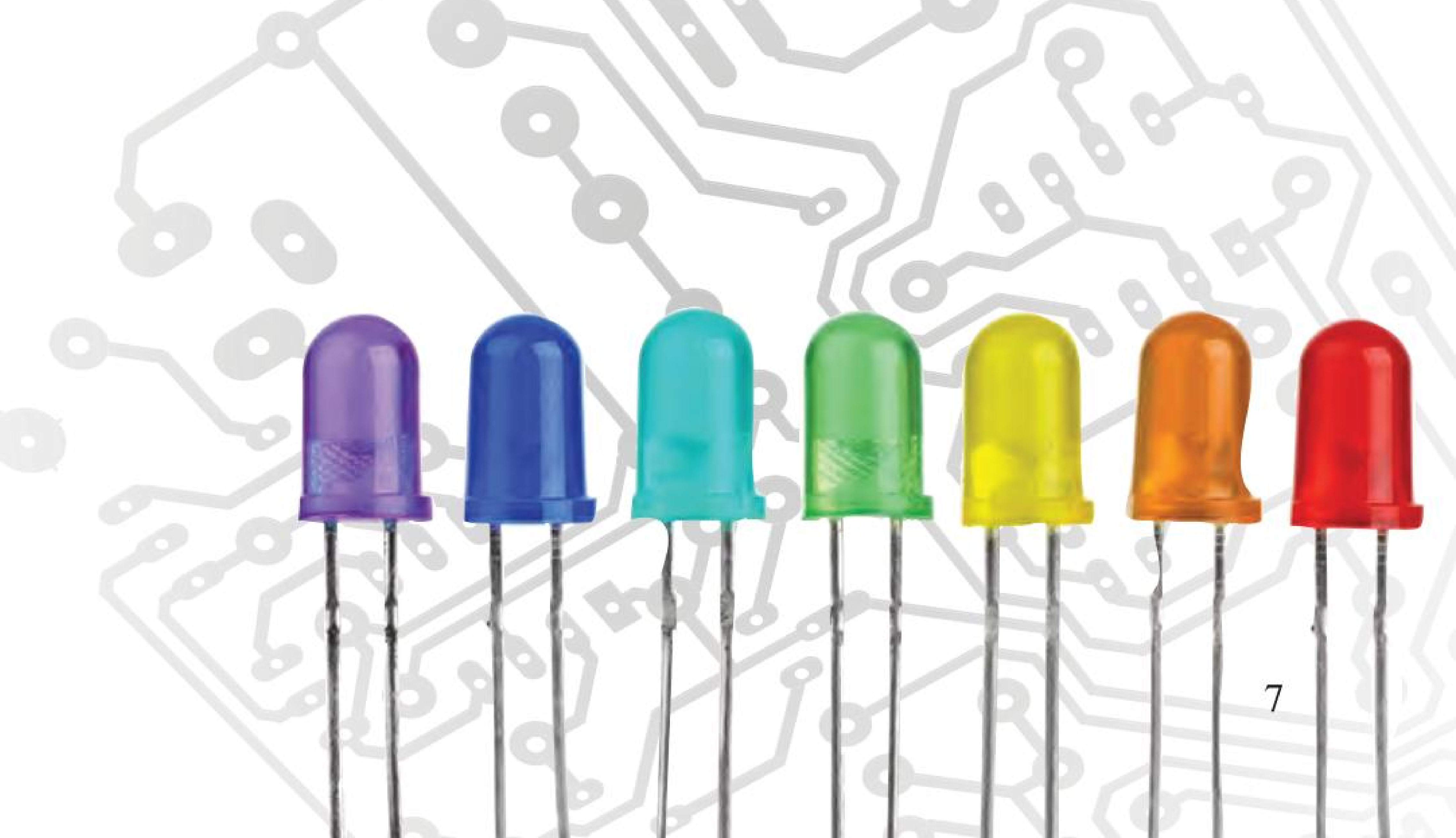
Building an AM Radio is of course nothing new; hobbyists have been constructing receivers since the age of the crystal set. But for me, that is one of its great attractions, it is a classic project with a long pedigree that teaches and rewards out of all proportion to the difficulty of actually building it. Pulling signals and stations out of 'the ether' with a circuit you have built yourself is a pleasure that never fails to bring a smile to the face. Indeed, for many of us it was our first proper project, and if you have never built one I urge you to give this one a try. It would also make a super project for inspiring children and future engineers at home or in school.

Audio Out

I really should have mentioned this last month (space issues prevented it) – we have a new regular column – *Audio Out* – and a new columnist – Jake Rothman. Jake is a designer and builder of audio equipment, and has also taught and lectured on the subject. Those of you with long memories may recall some of his projects in *EPE*, including a very successful and popular design for a fascinating electronic instrument called the 'Theremin'. Jake will be writing on the finer points of high quality audio design, but even if audio is not your particular interest, you will find his column very useful for tips on excellence in analogue electronics and construction.

Kickstarter congratulations to Mike

I couldn't sign off this month without mentioning Mike Hibbett's successful Kickstarter project, and as one of Mike's backers I can confirm that circuits have been delivered! He has covered the hard work needed to get his project up and running in *PIC n' Mix* this month, so I won't repeat his description, but I would like to offer 'thanks and congratulations' from everyone here at *EPE*. Designing, marketing, funding, manufacturing and delivering an electronic circuit really is quite an achievement, and I'd be delighted to hear from any readers who feel inspired by his example and are now considering a Kickstarter project of their own.



NEWS

A roundup of the latest Everyday News from the world of electronics

Broadband without landlines – report by Barry Fox

There is a booming new business in Japan – home or office broadband without the need for a fixed phone line. The electronics showrooms in the Akihabara 'Electric City' area of Tokyo are stuffed to the gills with router devices (mains-powered table-top units, or pocket dongles) which use a 4G SIM to provide broadband by Ethernet or Wi-Fi. A company called Softbank is the leading provider. On a recent trip I saw Softbank wireless routers providing high data speeds throughout several hotels.

Wireless broadband comes to London

Now the UK is getting its first taste of wireless broadband, from new service Relish, which promises 'fibre-fast broadband without the wires'.

So far available only in the London area, Relish delivers up to 65Mbps and on average 30Mbps, from a home Ethernet/Wi-Fi router that costs £50 and £20 a month for unlimited data; or 1GB mobile data for £10 a month from a pocket hub device that costs £35 and serves up to ten devices. Users who sign up for 12 months, and to both services, get free hardware and reduced prices.

The home router works only in London (with other urban areas promised) but the pocket hub roams for free on the Three 3G network outside London.

Customers order from Relish by phone or online and get a plug-and-play device delivered, pizza-style, the next day. Absolutely no landline is needed and a postcode database advises where in London the devices should and should not work. If reception proves impossible, for example in a basement, there is a money-back guarantee.

Relish is run by UK Broadband, which is owned by PCCW and Hong Kong Telecommunications. The company bought six 20MHz 4G channels in LTE Bands 42/43 (around 3.5GHz) and is so far using just one channel for the London service. The company's current licence from Ofcom authorises the use of two 20MHz blocks and UK Broadband recently asked Ofcom to grant an indefinite extension to the licence beyond the current expiry date of July 2018.

End of the landline? Many people now have a landline connection just for broadband – could wireless kill it off for good?

Government encouragement

Ofcom says it 'believes granting the request would promote competition and encourage investment and innovation' and will earn money for the government by applying an annual licence fee from the current expiry date.

The UK Broadband spectrum sits inside a wider 190MHz band of spectrum, between 3410 and 3600MHz and Ofcom plans to auction this off in 2015/16 to create competition – and earn the government more money.

The cost of the hardware, made by Huawei, is kept down by dedication to a limited range of channels. So far six other countries are using the same hardware, which adds economy of scale for manufacture.

Market research by the Centre for Economics and Business Research has shown what CEBR calls a 'landline tax' on broadband; London homes and small businesses are paying £193 million a year on landlines they neither want nor use, just to get broadband; and 47% of Londoners would prefer broadband without a landline.

Mobile broadband

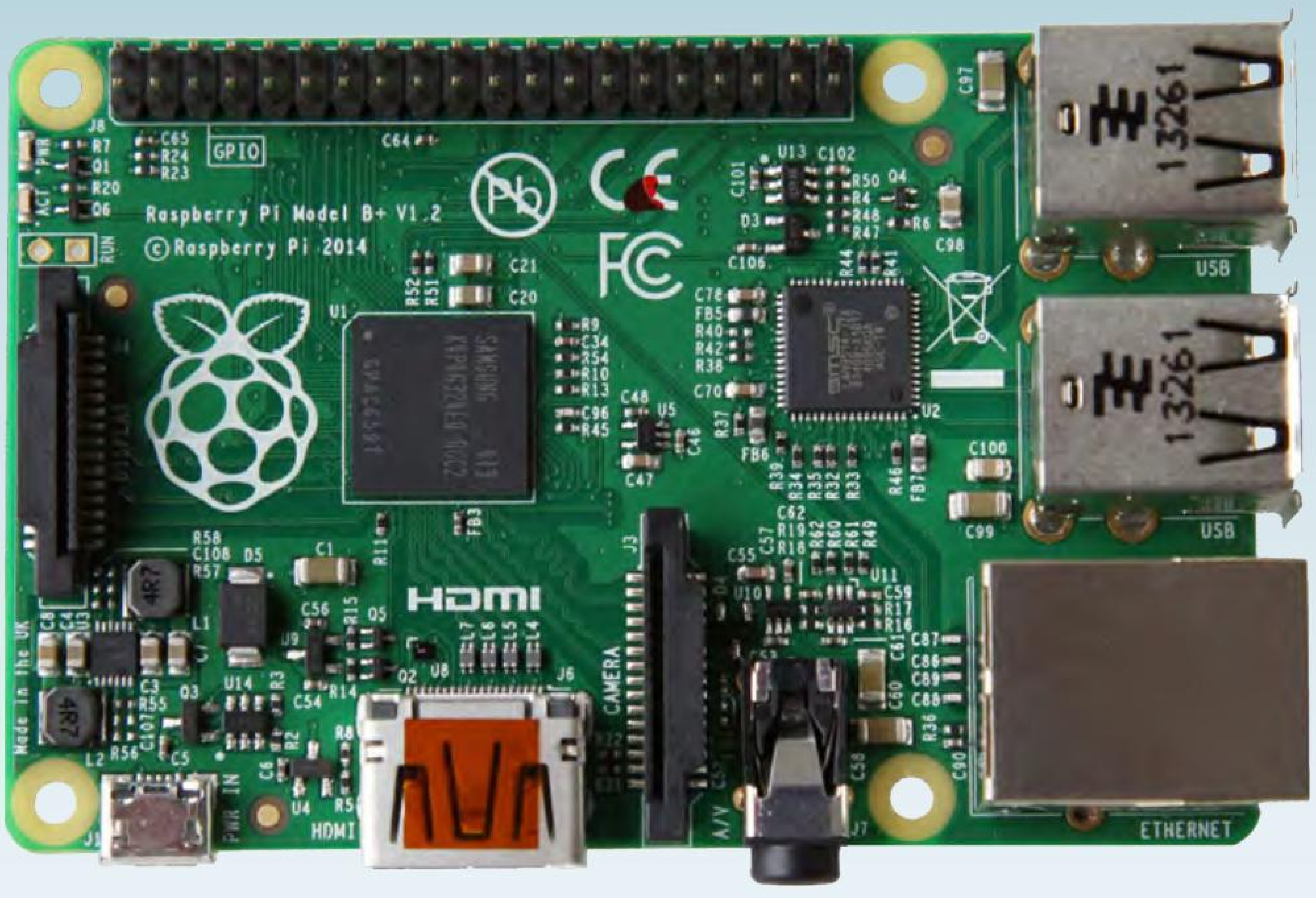
Currently there are many competing 3G and 4G mobile broadband services, which can in theory provide broadband without a landline. A data SIM in a dongle works as a Wi-Fi hotspot serving data to several devices at the same time. Three's MiFi was the first of the breed.

But these SIMs all require either a contract or monthly Pay-as-You-Go top-ups, with any remaining data credit expiring at the end of each month.

The one exception to this rule is the Three 321 PAYG SIM with rates of 3p a minute speech, 2p a text and 1p a MB of data. The data credit does not expire. The catch is that the SIM will not work in a dongle device like a MiFi to create a hotspot; the network detects that the SIM is in a dongle and refuses to serve data.

There is, however, a technical loophole. Modern smartphones can work as a mobile hotspot to provide Internet sharing or tethering to several devices, just like a MiFi dongle, and although Three's network attempts to detect and prevent this use with 321 SIMs, some phones (notably some Nokia Windows devices) fool the network. So the phone provides Wi-Fi tethering with a PAYG SIM and no 30-day data-use limit.

Raspberry Pi upgraded to B+ model



The Model B+ is the latest incarnation of the Raspberry Pi Foundation's credit-card-sized Linux computer. Despite some important upgrades its price is unchanged at US$35.

Building on the huge success of the Raspberry Pi Model B, with over three million boards now in use, The Raspberry Pi Foundation has announced the launch of the new Model B+, which incorporates a number of enhancements and new features.

Eben Upton, Raspberry Pi Founder and CEO of Raspberry Pi's engineering team said: 'This isn't a Raspberry Pi 2, but rather the final evolution of the original Raspberry Pi.'

So what's new?

The Model B+ uses the same BCM2835 application processor as the Model B. It runs the same software, and still has 512MB RAM; but the design team have made the following key improvements:

Better GPIO – more extensive GPIO capability is provided by the replacement of the 26-pin socket with a 40-pin connector: the pin-out of the first 26 pins remains identical to the Model B.

More USB connectivity – B+ has four USB 2.0 ports, compared to two on the Model B, and better hotplug and overcurrent behaviour. This enables users to avoid the use of a cascading hub when deploying multiple devices such as a wired keyboard, mouse, wireless dongle and external hard drive.

Micro SD – In keeping with current trends, the standard SD card form factor has been replaced by a microSD card format. The old friction-fit SD card socket has been replaced with a much nicer push-push micro SD version.

Lower power consumption – there has been a 20% to 30% improvement in power consumption on the Model B+ by using a more efficient switched-mode power supply in place of the previous linear arrangement. This has achieved a reduction in consumption of between 0.5W and 1W – a feature welcomed by designers of low-power projects.

Better audio – the audio circuit incorporates a dedicated low-noise power supply and audio output quality has also been improved with some DSP-related fixes.

USB connectors – these are now aligned with the board edge, and the composite video has been moved onto the 3.5mm jack.

Neater form factor – some small changes have also been made to the board form factor in order to provide better alignment of connectors on the side of the board. In addition, four squarely-placed mounting holes instead of two are now provided to facilitate improved board stability when mounted within an OEM application.

Get your new Raspberry Pi now!

The Raspberry Pi Model B+ is available to purchase direct from RS Components and Farnell/Element14 for immediate shipment priced at US$35 in single unit quantities. Production of the Model B will continue and will be sold alongside the Model B+.

More details are available online at: **http://youtu.be/KtKSyN0x6sk** and **http://youtu.be/iP3RxoxYMFw**

Supercapacitors challenge lithium-ion batteries

Market research company IDTechEx has recently reported that supercapacitors are improving faster than lithium-ion batteries in most respects – for example, Nanotune Technologies has demonstrated supercapacitors with 35Wh/kg, claiming that 500Wh/kg may be achievable – two to four times the energy density of the best lithium-ion batteries.

Dr Peter Harrop, Chairman of IDTechEx, said: 'Supercapacitors need not match lithium-ion battery *energy density* to replace much of that battery market. They have replaced maybe one percent of that market already because they last longer than, for example, the public transport buses they are used in. They are safer and have ten times the *power density*. They have replaced lithium-ion batteries in most Chinese buses, despite greater up-front price… few dispute that in the next decade, at around 100Wh/kg with acceptable other parameters, supercapacitors or "supercabatteries" could grab 50% of the lithium-ion market, reaching tens of billions of dollars in yearly sales.'

i-Bell Wi-Fi doorbell

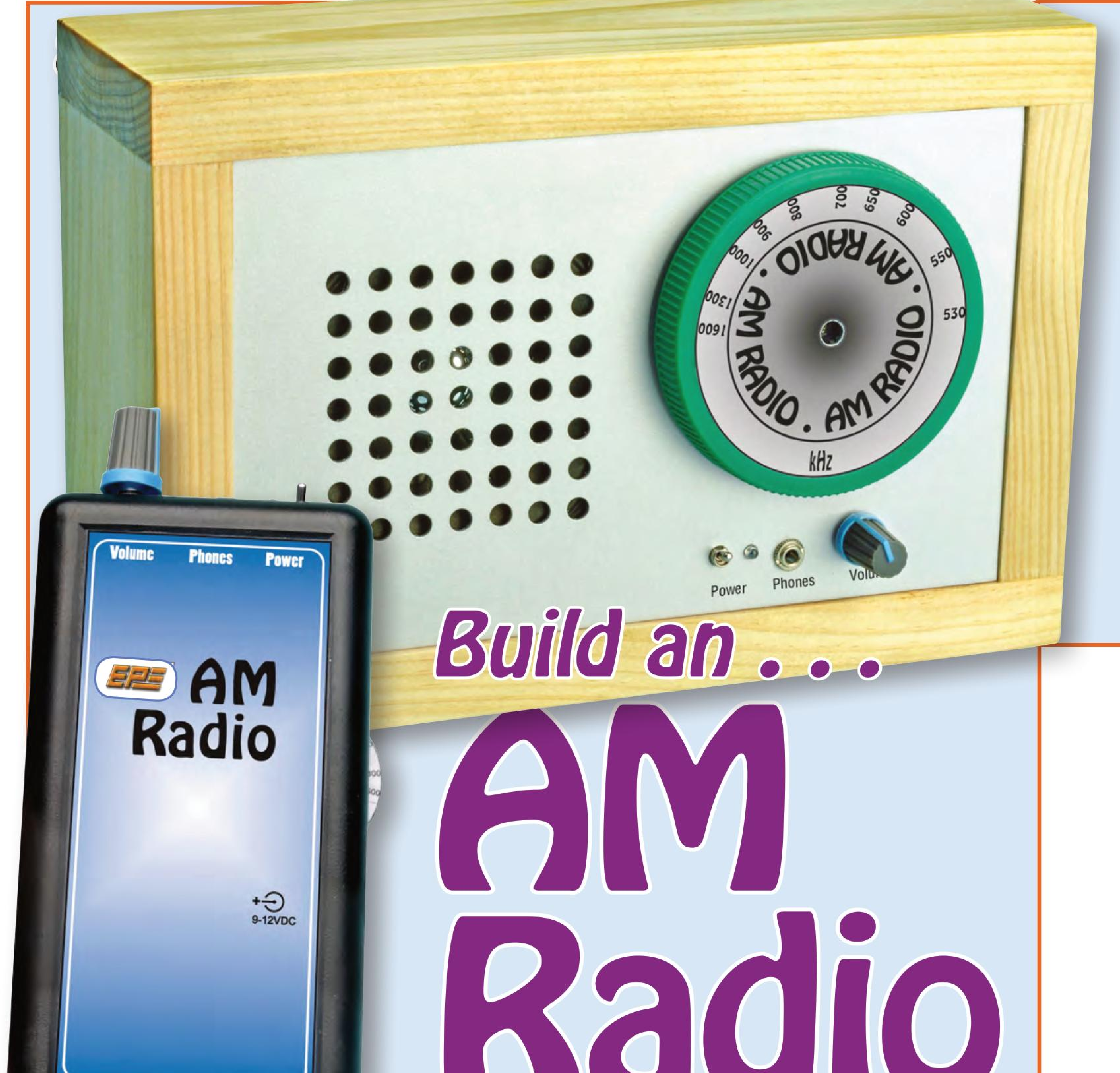
A Wi-Fi-enabled camera doorbell has been launched with a crowdfunding campaign, making it possible to monitor who is at your door, even when you are away form home.

Acting as an interactive peephole for the front door, the 'i-Bell' is part of the next generation of home automation and the Internet of Things.

It's a wireless gadget that allows smartphone users to see and communicate with whoever is standing on their doorstep, whether they are home or away – putting an end to failed deliveries and ensuring users have full control over their front door. The crowdfunding campaign, launched in July on Kickstarter, aims to finance the manufacturing process: **https://www.kickstarter.com/projects/729057054/i-bell**

i-Bell is designed and will be made in the UK, and will be fully compatible with Apple's recently announced HomeKit, which adds smart devices to the home via individual apps.

To find out more about i-Bell, visit the website: **www.i-bell.co.uk**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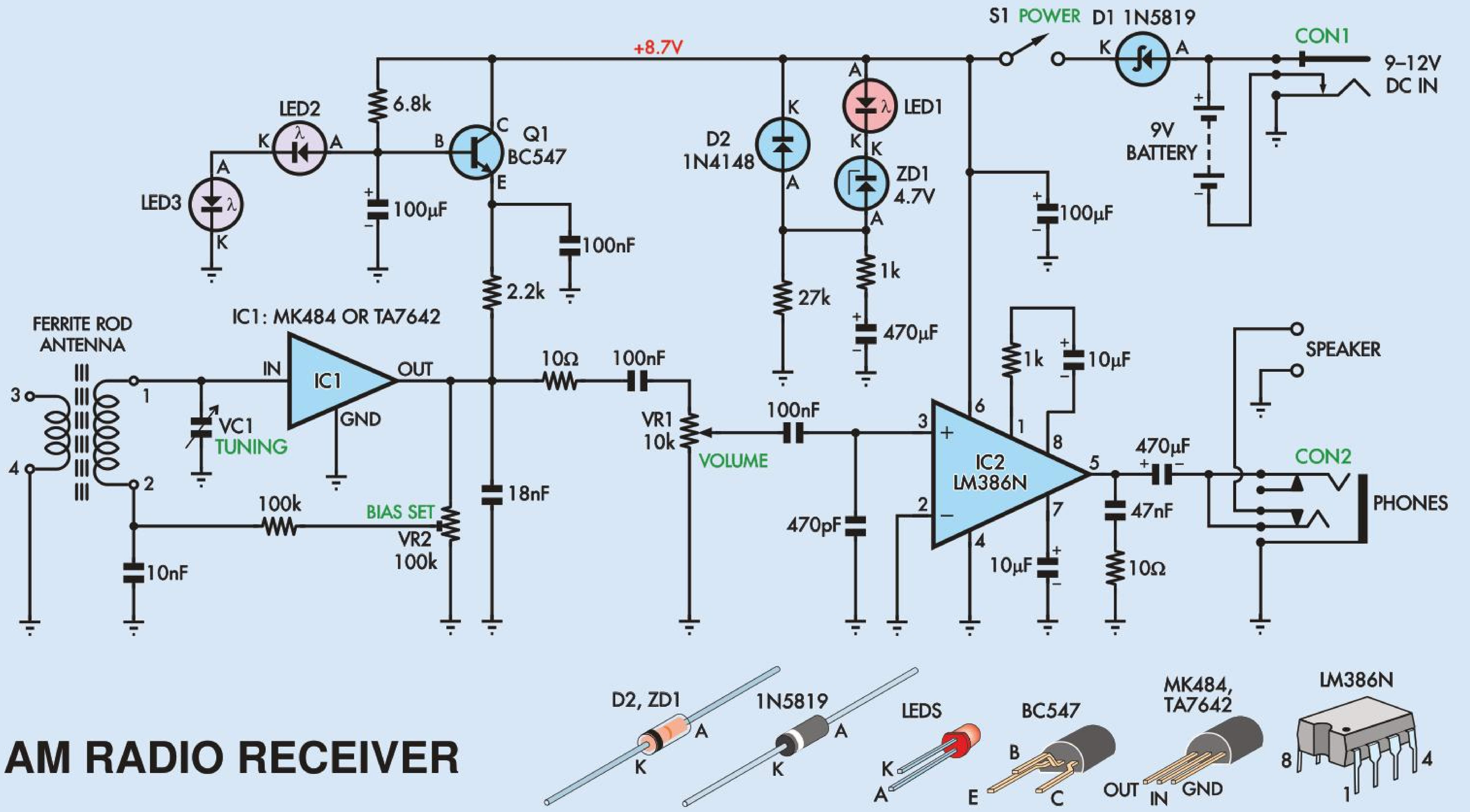
AM Radio

By JOHN CLARKE

This simple AM radio can built in two forms. One is shirt-pocket size, not much larger than an Android phone, which drives headphones or ear-buds. The other is a retro-style mantel radio with a hand span dial and a 100mm (4-inch) loudspeaker in a basic timber cabinet.



AM RADIO RECEIVER

Fig.1: the circuit is based on an MK484 (or TA7642) radio receiver IC. This amplifies and detects the tuned RF signal and drives an LM386N audio amplifier. Q1, LED2 and LED3 provide a regulated 1.4V rail for IC1.

WANT A SIMPLE radio that you, your children or grand-children can easily build? This one uses a small PCB with two ICs and not a great deal more. It's not a superheterodyne, so the alignment is very simple, and you don't need any special equipment.

The pocket-sized version is housed in a remote-control case incorporating a 9V battery compartment. There is the option to power it from a 9-12VDC external supply (eg, a plugpack) and to drive an external loudspeaker. It is tuned using a rotary thumbwheel dial and has a volume control, battery condition indicator and power switch.

The retro-style desktop version is designed to look a little like the old AM radios of a bygone era that took pride of place on top of the fireplace mantel. It incorporates a loudspeaker and a hand-span tuning dial. It is housed in a small timber box with an aluminium front panel and this carries the volume control, battery condition indicator and power switch. The sound from the loudspeaker is not overly loud, but is quite sufficient for personal listening.

AM radio IC

The circuit for the *AM Radio Receiver* is based on a single IC that includes RF (radio frequency) amplification, a detector and AGC (automatic gain control). A similar device was originally available in 1984 from Ferranti Semiconductors; known as the ZN414Z, it is now obsolete. The MK484 replaces this, and although out of production, there are remaining stocks (eg, on **ebay.co.uk**). Additionally, the TA7642 is also now available with similar performance to the MK484. These AM radio ICs will work from 150kHz to 3MHz.

Add a tuning coil, a variable capacitor plus some capacitors and resistors and the IC becomes a fully functional AM receiver. For our circuit, the receiver operates over the standard AM radio band of 531-1602kHz. The signal output from the IC is amplified to drive a pair of headphones or a loudspeaker.

We tested both the TA7642 and MK484 in our circuit and found that the TA7642 has greater sensitivity than the MK484. However, its selectivity is wider, ie, it's not as good. This means that the TA7642 will exhibit greater crosstalk (or interference) between stations that have adjacent frequencies. We did not test a ZN414Z simply because we didn't have one available.

Note that while the performance of this *AM Radio Receiver* is acceptable, it does not have the selectivity and sound quality that's available from a superheterodyne receiver.

Specifications

Tuning frequency: approx: 531-1602kHz

Output power: ~300mW into 4Ω

Operating current: typically 27mA

Circuit details

The full circuit for the *AM Radio Receiver* is shown in Fig.1. IC1 is the AM radio chip. We have reproduced its equivalent circuit in Fig.2 (from the TA7642 data sheet). This is a 'tuned radio frequency' or TRF circuit, and it combines a high-gain RF (radio frequency) amplifier and a detector to recover the audio signal. It is not a regenerative or reactive receiver.

The inductance of the ferrite antenna rod (L1) and variable capacitor VC1 form a tuned parallel resonant circuit. This has a high impedance at the tuned frequency and a low impedance at other frequencies.

IC1 amplifies the tuned signal and then its internal detector rectifies and amplifies the resultant audio frequen-

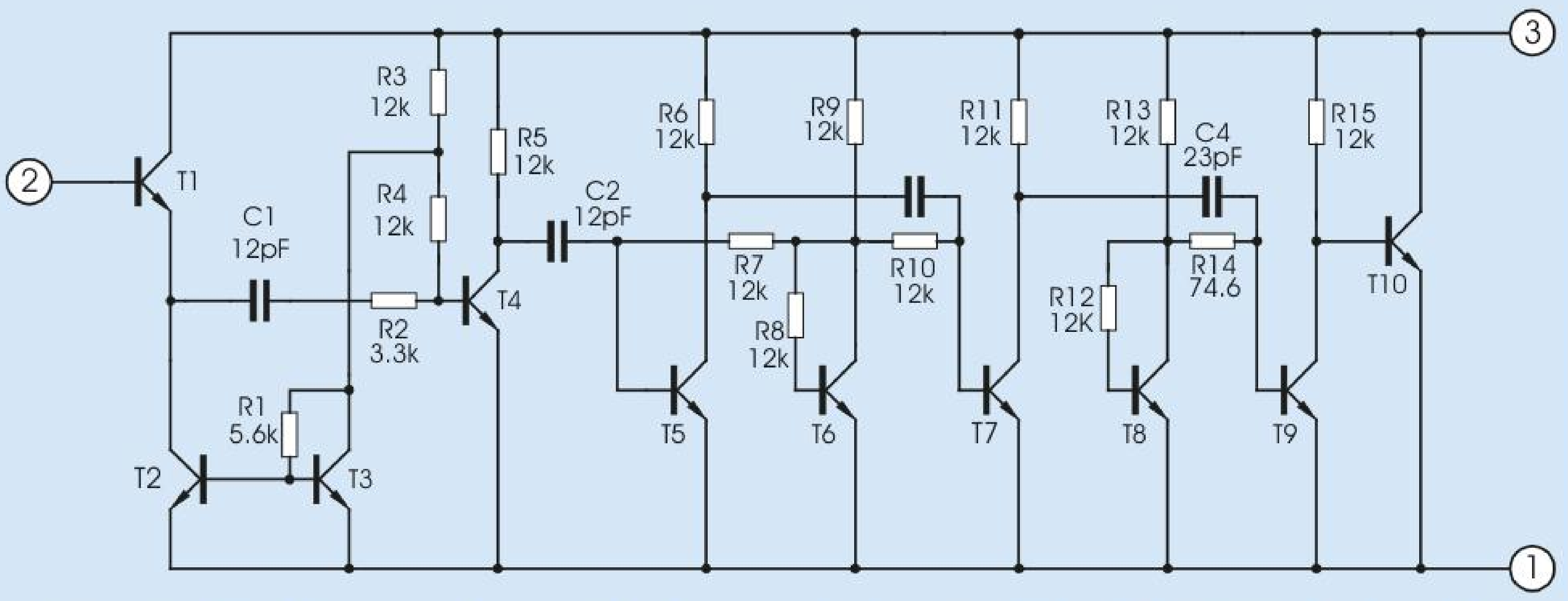


Fig.2: this diagram shows the internal circuit of the TA7641 single-chip AM radio receiver. It includes an RF amplifier, a detector and automatic gain control (AGC) – see text.

cies. IC1 is a 3-pin device with its AC output and DC power supply input using the same pin.

One-chip AM radio

The internal workings of IC1 are quite interesting. While it contains 10 transistors (and a number of resistors and capacitors), there are three RF amplifier stages. Transistor T1 is an emitter-follower to provide a high input impedance. T2 is its load and operates as a current sink, biased by T3 and R1.

The signal is then AC-coupled to T4, the first RF amplifier stage. This operates as a common-emitter amplifier with a 12kΩ collector load, while transistor T3 also provides its DC bias. The output is then AC-coupled to T5, the second RF amplifier stage. Again, it has a 12kΩ collector load and its DC bias is provided by transistor T6. The third amplifier stage, formed by transistor T7 shares the same bias generator.

The output is then AC-coupled to the detector, transistor T9. This is critically biased by transistor T8 (note the low-value resistor from its collector). The result is that it rectifies and amplifies the modulated signal – the audio. This is then amplified and buffered by transistor T10, again a common-emitter amplifier, which has its collector connected to the output pin.

The output pin is connected to an external capacitor (18nF in our case) which filters out most of the RF carrier, leaving the original modulating signal which is the audio we want to hear.

That's all relatively straightforward, but this chip also includes an automatic gain control (AGC) function and it's less apparent how that operates. The point of AGC is to reduce the amount of RF amplification for strong stations, so that the audio output level doesn't vary too much between strong and weak stations.

While Fig.2 is only an equivalent schematic and doesn't necessarily show exactly what is going on in the IC, it seems likely the shared biasing arrangement of both T3 and T6 provides this AGC action. With stronger signals, the increased modulation on the later stages causes the bias on the earlier stages to change so that their gain is reduced.

Back to the circuit

While IC1 has internal AGC, its output signal amplitude still varies somewhat with station strength. Trimpot VR2 and its associated 100kΩ resistor allow the overall RF gain (and AGC) to be adjusted to suit the signal strength at your location. When VR2 is adjusted, the DC bias at IC1's input shifts and this changes the bias on its buffer stage and thus the signal level that's fed to the following RF gain stages.

Speaking of the buffer stage, its high input impedance (around 3MΩ) minimises the loading on the tuned circuit, providing optimal operating conditions. The resonant circuit is designed with a high 'Q' factor to ensure good selectivity between adjacent stations. This is important because a TRF receiver amplifies whatever signal is picked up and so there is always some risk that strong adjacent stations can 'break through'.

The supply voltage for IC1 is applied to its OUT terminal and this is derived via transistor Q1 and a 2.2kΩ resistor. The demodulated AM signal also appears at the OUT terminal and the 18nF capacitor to ground rolls off the audio response above 4kHz.

IC1 has a limited operating voltage range of 1.2-1.6V. This is provided by a simple voltage regulator comprising Q1, LED2 and LED3. These two LEDs are infrared types and have a forward voltage of approximately 1V when low current flows through them. This forward voltage is remarkably constant for a wide range of currents. In fact, tests of several infrared LEDs from different manufacturers showed that their forward voltage is around 1.09V at 1.6mA, dropping slightly to 0.945V at 160µA.

Connecting two such LEDs in series provides a reasonably stable 2V reference and these are fed with about 1mA via a 6.8kΩ resistor from the 8.7V supply rail. This 2V reference is applied to the base of transistor Q1 and so about 1.4V appears at its emitter (due to the 0.6V base-emitter voltage drop). This voltage is then used to power IC1 via the 2.2kΩ resistor, as described above.

Audio amplifier stage

IC1's audio output is fed via a 10Ω RF (radio frequency) stopper resistor and a 100nF capacitor to volume potentiometer VR1. The signal at VR1's wiper is then AC-coupled via another 100nF capacitor to pin 3 of IC2, an LM386N audio power amplifier.

The inverting input (pin 2) of IC2 is grounded and the amplifier has a gain of close to 50, as set by the 1kΩ resistor and series 10µF capacitor between pins 1 and 8. The power supply at pin 6 is bypassed with a 100µF capacitor, while a separate 10µF bypass at pin 7 removes supply ripple from the amplifier input stages.

IC2's amplified output appears at pin 5 and is AC-coupled via a 470µF capacitor to stereo headphone socket CON2. This allows either a loudspeaker or a set of headphones to be used. Plugging in the headphones automatically disconnects the loudspeaker.

The 470µF capacitor provides low-frequency roll-off below 21Hz for 32Ω stereo headphones (which are connected in parallel) while for a 4Ω load, the low-frequency roll-off is below 85Hz. In addition, a Zobel network comprising a 10Ω resistor and a 47nF capacitor is connected from IC2's pin 5 output to ground to prevent instability.

Assuming a 9V power supply, IC2 can provide about 300mW into a 4Ω load. Its distortion is typically around 0.2%, rising to 3% at the 300mW level. The power output is reduced to

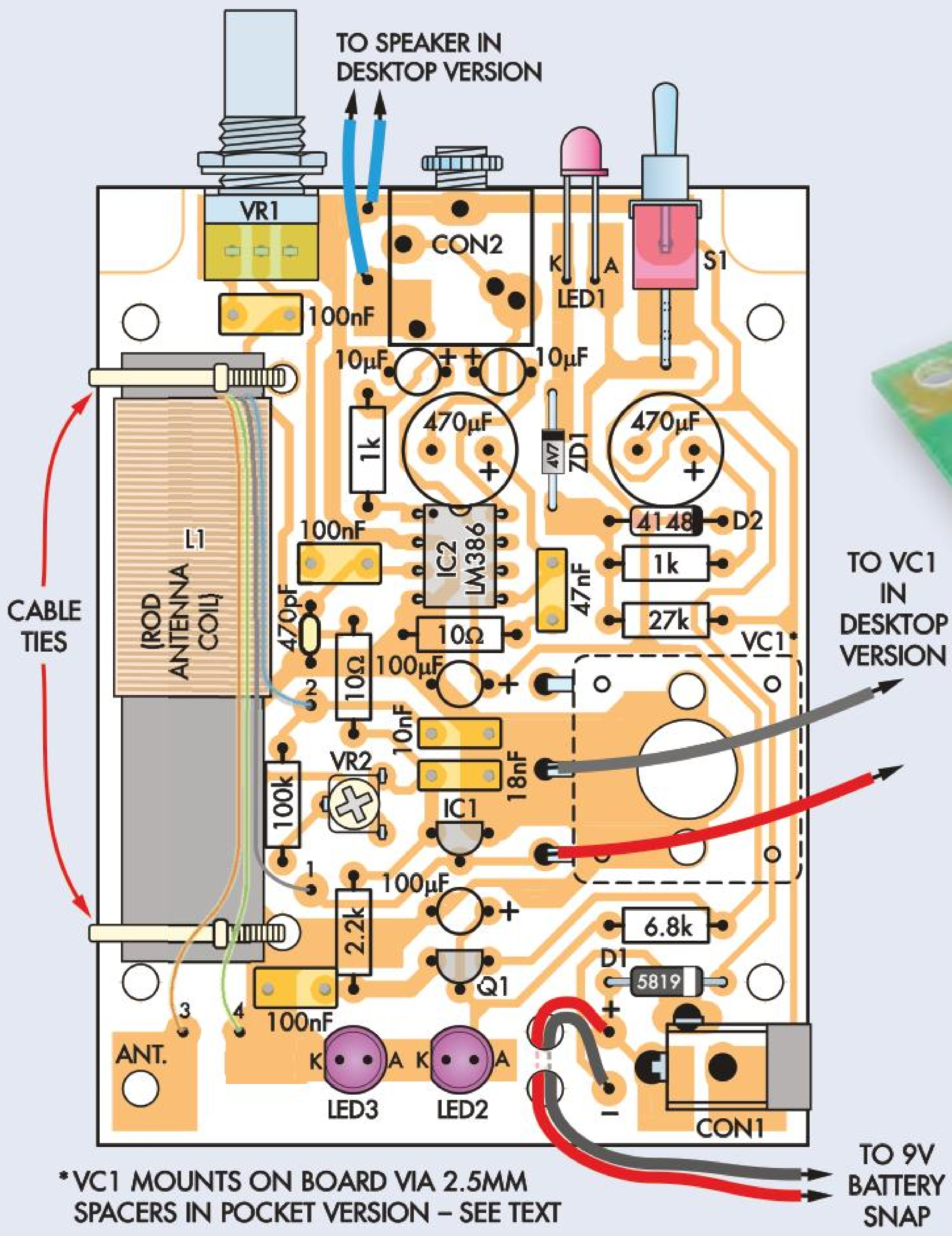
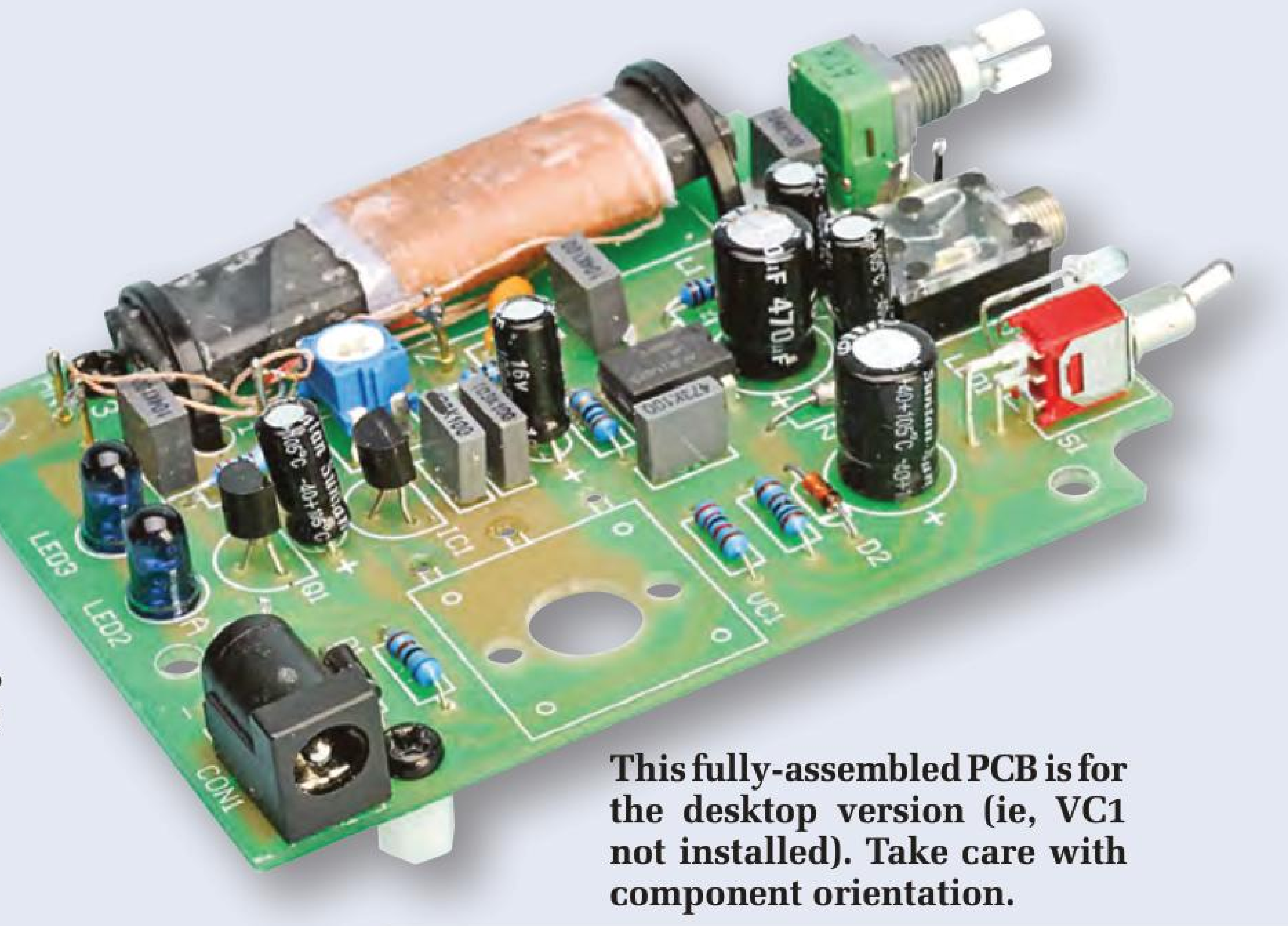

TO SPEAKER IN DESKTOP VERSION
VR1
CON2
LED1
K
A
S1
100nF
10µF
10µF
470µF
470µF
1k
ZD1
4V7
4148
D2
1k
27k
IC2
LM386
100nF
47nF
L1
(ROD ANTENNA COIL)
CABLE TIES
470pF
10Ω
10Ω
100µF
VC1*
TO VC1 IN DESKTOP VERSION
10nF
18nF
VR2
IC1
100k
100µF
2.2k
6.8k
D1
5819
Q1
100nF
ANT.
LED3
LED2
CON1
TO 9V BATTERY SNAP
*VC1 MOUNTS ON BOARD VIA 2.5MM SPACERS IN POCKET VERSION – SEE TEXT

Fig.3: install the parts on the PCB as shown in this diagram. Note that tuning capacitor VC1 is mounted on the PCB for the pocket version only.



This fully-assembled PCB is for the desktop version (ie, VC1 not installed). Take care with component orientation.

about 160mW when using 32Ω stereo headphones, but this is more than enough to provide sufficient volume.

Power supply

Power for the *AM Radio Receiver* can come from either a 9V battery or an external 9-12V DC plugpack. When the external supply is plugged into the DC socket, the 9V battery is automatically disconnected. Diode D1 provides reverse polarity protection, while S1 is the power on/off switch.

Note that a 1N5819 Schottky diode is used for D1, to limit the voltage drop across it to about 0.3V.

LED1 is used as a battery condition indicator at switch-on and then functions as a power-on indicator. It operates as follows: when power is first applied, current flows through LED1, 4.7V Zener diode ZD1 and a 1kΩ resistor into a 470µF capacitor, which is initially discharged. If the 9V battery is fresh, it provides 8.7V at LED1's anode. This voltage is then dropped by about 1.8V across LED1 and by 4.7V across ZD1, leaving 2.2V across the series 1kΩ resistor (ie, when the 470µF capacitor is discharged). As a result, LED1 lights with about 2.2mA initially flowing through it.

At lower battery voltages, there is less voltage across the 1kΩ resistor. As a result, less current flows through LED1 and its initial brightness is reduced. In fact, when the battery voltage eventually gets down to 7V, there is only about 0.2V across the 1kΩ resistor and LED1 barely lights, indicating that the battery has gone 'flat'.

After switch-on, the current through LED1 is progressively reduced as the 470µF capacitor charges and so the LED quickly dims. It doesn't turn off completely though, since the associated 27kΩ resistor ensures that it just remains on, with about 80µA through it. LED1 now indicates that the power is on, but the current through it is dramatically reduced to conserve the battery.

When power is switched off, diode D2 discharges the 470µF capacitor so that LED1 is ready to indicate the battery condition the next time the unit is turned on.

PCB assembly

The *AM Radio Receiver* is built onto a PCB coded 06101121, which measures

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
100nF	0.1µF	100n	104
47nF	0.047µF	47n	473
18nF	0.018µF	18n	183
10nF	0.01µF	10n	103
470pF	NA	470p	471

Table 1: Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	100kΩ	brown black yellow brown	brown black black orange brown
☐	1	27kΩ	red violet orange brown	red violet black red brown
☐	1	6.8kΩ	blue grey red brown	blue grey black brown brown
☐	1	2.2kΩ	red red red brown	red red black brown brown
☐	2	1kΩ	brown black red brown	brown black black brown brown
☐	2	10Ω	brown black black brown	brown black black gold brown

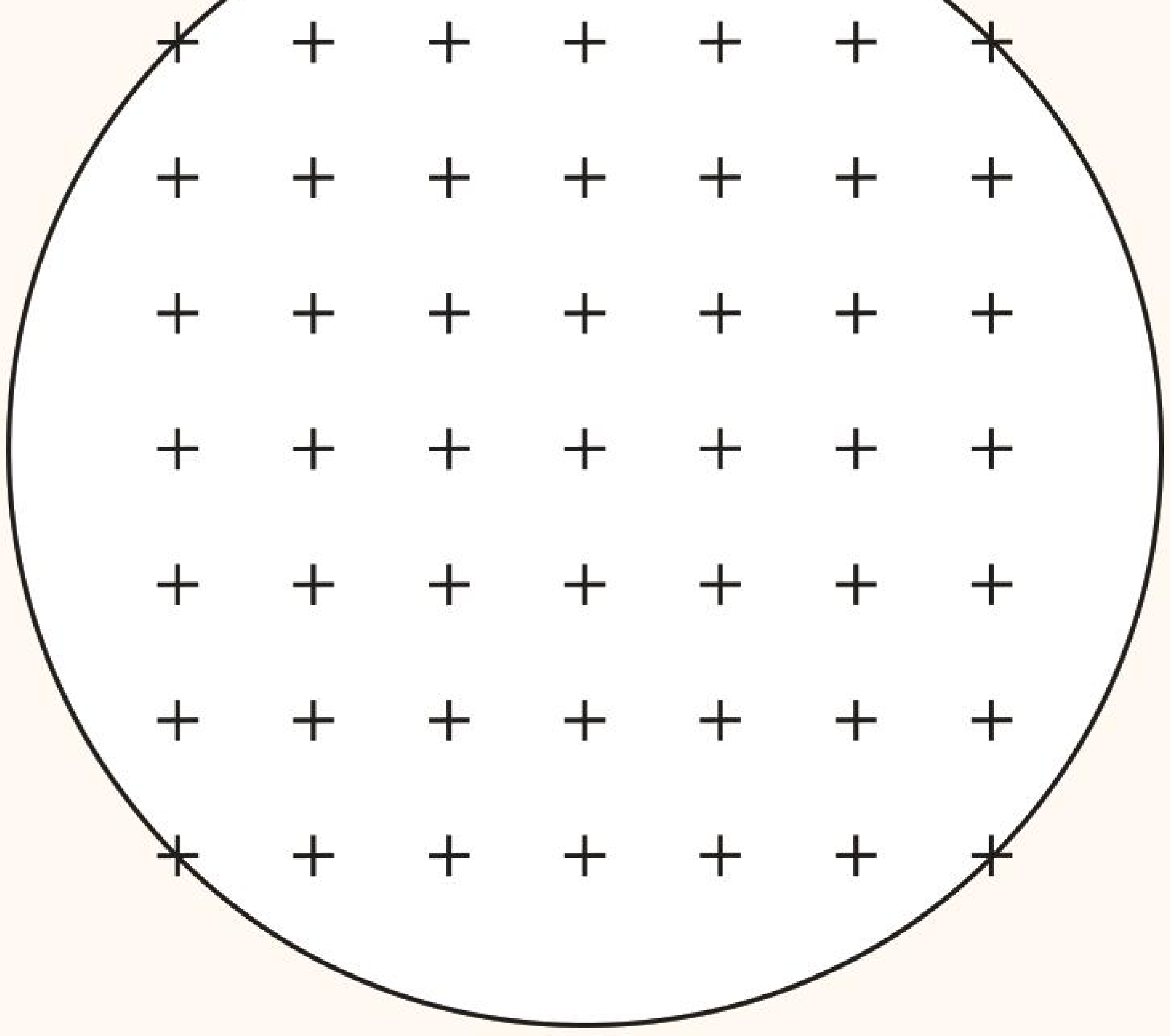


Fig.4: this is the drilling template for the loudspeaker grille in the desktop version. Drill and ream all holes to 5mm.

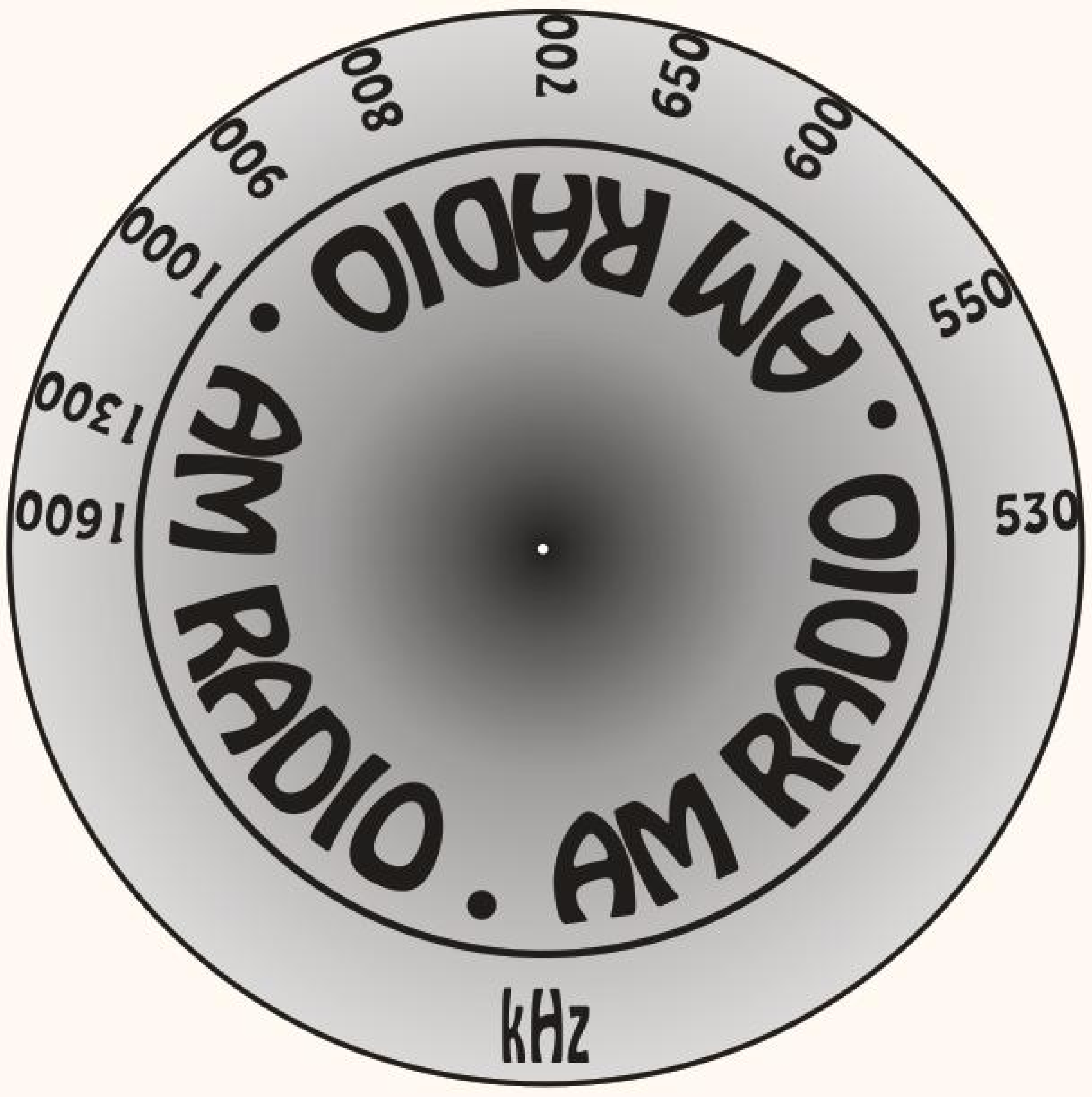


Fig.5: the dial label for the desktop version. It can be downloaded in PDF format from the *EPE* website.

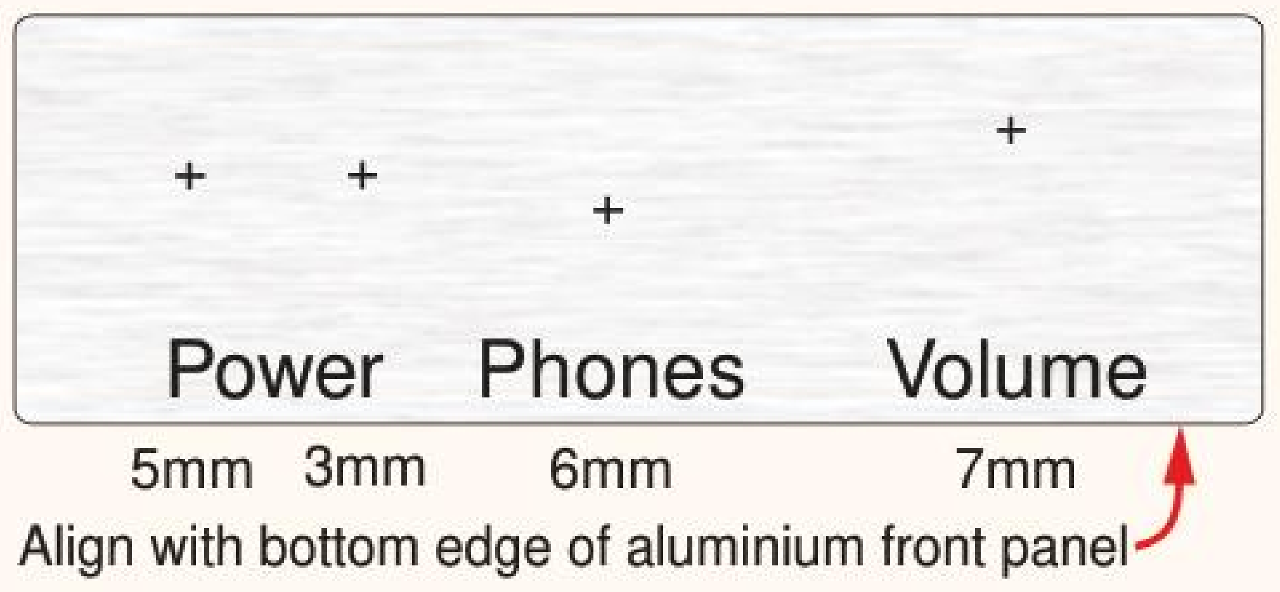
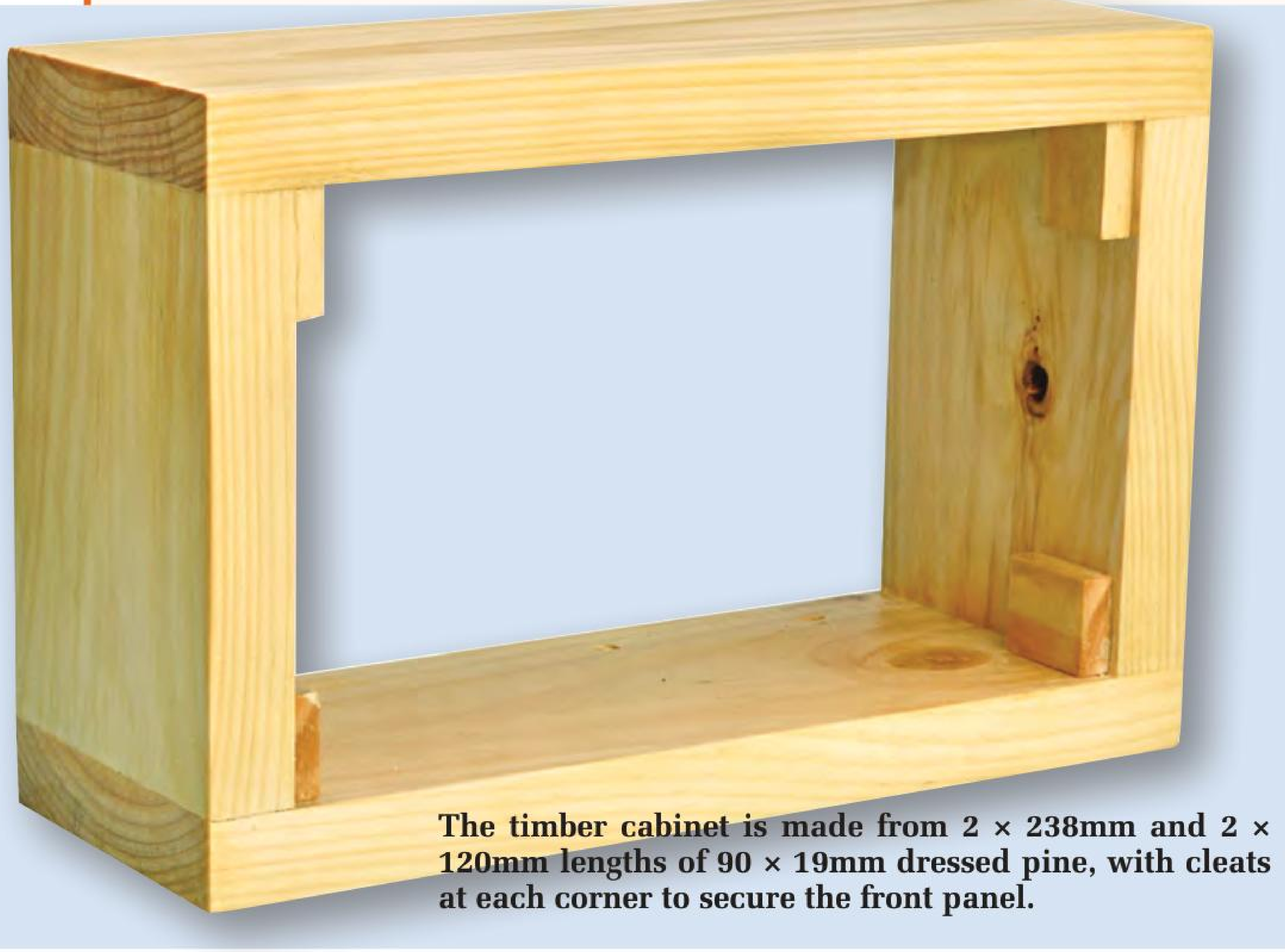


Fig.6: the drilling template and control panel for the desktop version.



The timber cabinet is made from 2 × 238mm and 2 × 120mm lengths of 90 × 19mm dressed pine, with cleats at each corner to secure the front panel.

65mm × 86mm, and is available from the *EPE PCB Service*. This PCB is used for both the pocket and desktop versions. The only difference is that for the pocket version, you will need to make the corner cut-outs at one end of the board, adjacent to VR1 and switch S1, to allow the board to clear a couple of pillars in the case. In practice, it's just a matter of using a small hacksaw to cut away the corners and then filing the cut-outs to shape.

Fig.3 shows the assembly details for the PCB. Before installing any parts, check that the corner mounting holes and the holes for the cable ties are all 3mm in diameter. That done, start the assembly by installing the resistors, Zener diode ZD1 and diodes D1 and D2. Note that the diodes must all be correctly oriented, as shown on Fig.3.

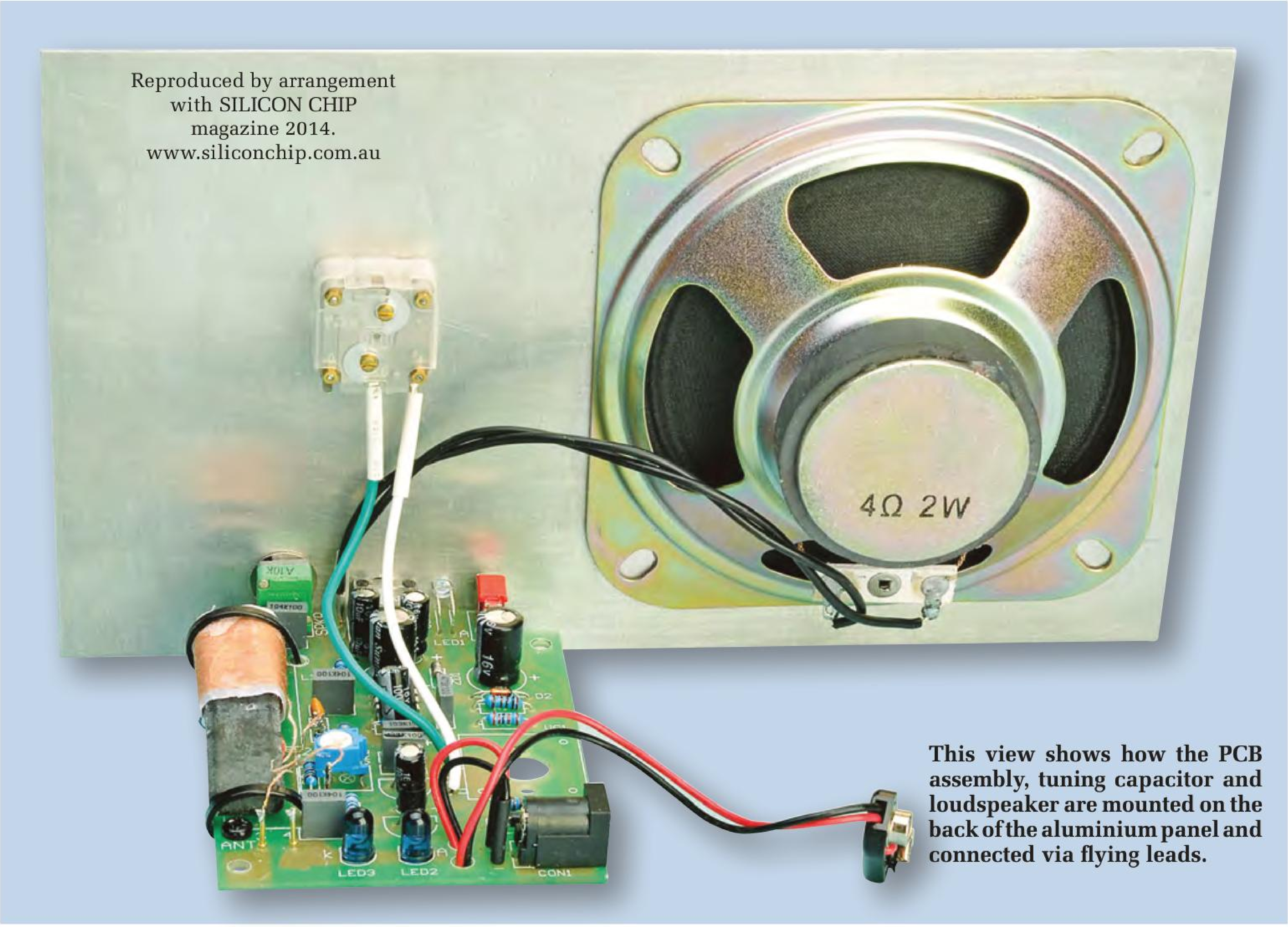
Table 1 shows the resistor colour codes, but it's also advisable to check each one using a digital multimeter (DMM) before installing it.

Next, install PCB stakes at the external wiring points, followed by the MKT and ceramic capacitors, then IC1, transistor Q1 and IC2 (LM386N). The latter can either be soldered to the board or you can mount it via an 8-pin IC socket. Make sure that it goes in the right way around.

IC1 and Q1 must also be correctly oriented. Fig.3 shows how to install IC1 if using an MK484 or TA7642 device. **If you have a Ferranti ZN414Z in your parts drawer, then this can also be used, but note that its GND and OUT pins are reversed compared to the MK484 and TA7642.** This means that it would have to be rotated 180° when installing it on the PCB (ie, install it with its flat side towards Q1).

Installing the LEDs

LED1 (red) is mounted by first bending its leads down through 90° exactly 7mm from its body. It's then installed with the centre of its lens 6mm above the PCB and this can be done by pushing its leads down onto



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This view shows how the PCB assembly, tuning capacitor and loudspeaker are mounted on the back of the aluminium panel and connected via flying leads.

a 6mm-high cardboard spacer. Its anode lead is the longer of the two and the LED must go in with this lead adjacent to switch S1.

The two infrared LEDs (LED2 and 3) are mounted by pushing them all the way down onto the PCB before soldering their leads (they simply provide a voltage reference for transistor Q1).

The electrolytic capacitors can go in next and these must be oriented as shown on Fig.3. Make sure that the tops of these capacitors are no more than 12.5mm above the PCB if building the pocket version, otherwise the lid of the case will not fit correctly. Once they're in, install potentiometer VR1, trimpot VR2, switch S1, the DC socket (CON1) and the 3.5mm stereo socket (CON2).

Installing the antenna rod

Two 100mm cable ties are used to secure the ferrite rod antenna to the PCB. Once it's in place, separate out the four wires for the two coils and find the two that have the greatest resistance. On our prototype, the main winding on the ferrite rod measured about 10Ω, while the separate antenna winding measured 2Ω.

The next step is to connect the coil with the 10Ω resistance to PC stakes '1' and '2'. You will find that one of the leads of this winding emerges from inside the coil – this is the wire to connect to PC stake 1. For the rod used in our prototype, it's also the unmarked lead.

The other lead of the 10Ω winding goes to PC stake 2 and this wire will have a blue marking. Connecting the main coil in this way will give the highest selectivity (ie, the highest Q).

The other two wires (ie, in the 2Ω antenna winding) are marked red and green. These go to PC stakes 3 and 4 and can be connected either way around.

Installing VC1

Variable capacitor VC1 is mounted on the front panel in the desktop version and is connected via flying leads (see photo). So, if you're building this version, just solder two 100mm-long lengths of light-duty hook-up wire to VC1's pads for the time being – see Fig.3.

Alternatively, if you're building the pocket version, VC1 is mounted on the PCB itself. **It's not just a matter of installing it flush with the PCB though – instead, it has to be mounted 2.5mm above the PCB using a couple of spacers, so that the tuning thumbwheel doesn't later foul the bottom of the case.** You can use a couple of TO-220 insulating bushes as the spacers and you must secure the assembly using two M2.5 × 6mm machine screws.

Don't use screws that are longer than 6mm, otherwise they will foul the plates inside VC1 and you won't be able to turn the tuning shaft.

The battery clip lead can now be connected to its PC stakes, adjacent to CON1. Be sure to loop the leads through the two strain relief holes in the PCB.

Note that if you are building the pocket version, the battery clip must be first placed inside the battery compartment. Its leads are then fed out through a slot at one end and looped through the holes in the PCB.

Building the pocket version

Preparing the case that's used to house the pocket version mainly involves drilling its end panel, to provide clearance holes for VR1, CON2, LED1 and power switch S1. The control panel label shown as Fig.7 indicates the drilling details and can be downloaded as a PDF file from the EPE website.

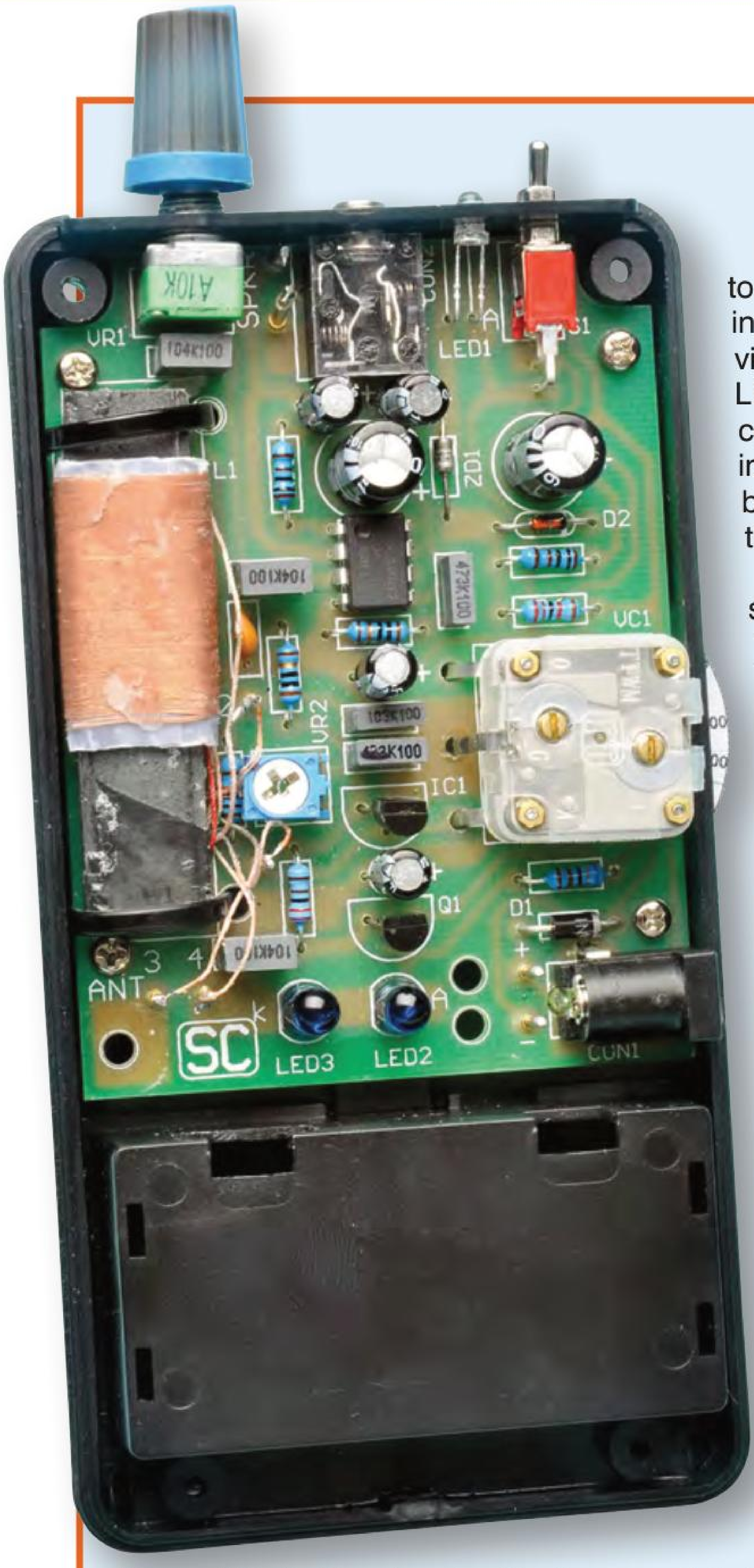
Print the label out, trim off the hole size markings and attach it to the end panel using double-sided adhesive tape. Alternatively, you can print the label onto adhesive-backed photo-paper and attach it directly to the panel. The holes can then be drilled to the sizes indicated. Use a 1mm pilot drill to start each hole, to ensure accuracy.

In addition, you will have to mark out and cut a hole in one side of the case for the DC connector. You can determine the location of this circular cut-out by temporarily positioning the PCB in the case. A rat-tail file is then used to make the cut-out and you will need to remove material from both the top (mostly) and bottom sections.

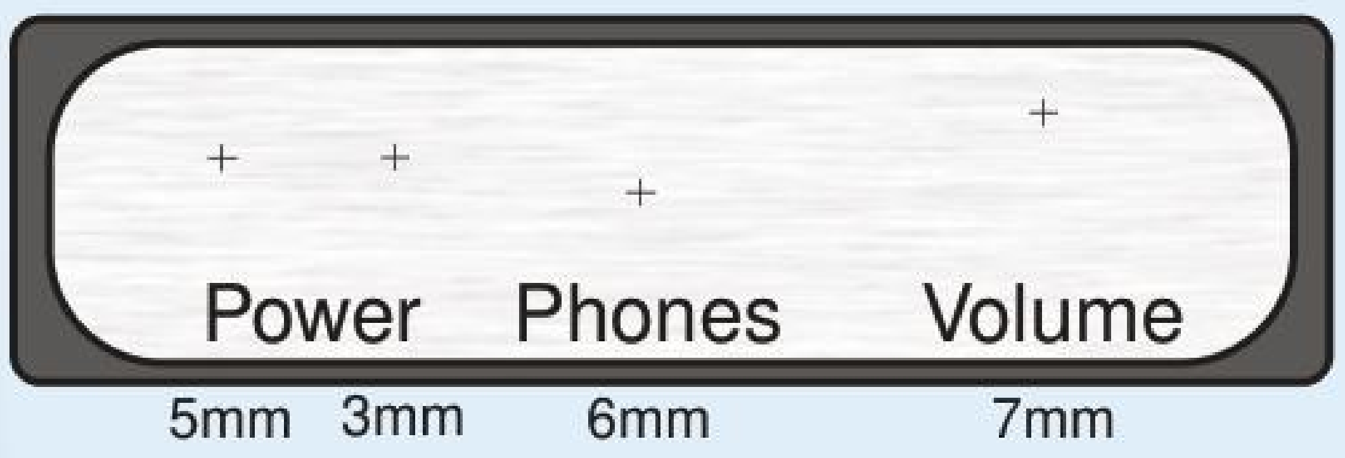
A slot is also required in the bottom section for the tuning thumbwheel. The bottom of this slot is flush with the inside base of the case and is 4mm high × 29mm wide, centred on VC1's tuning shaft.

Fig.8 shows the thumbwheel dial label. Print it out and carefully trim it to size before attaching it to the plastic thumbwheel. It must be affixed to the top of the thumbwheel and must be oriented correctly so that the full range of dial markings will be available over the 180° tuning range.

The pocket version assembly can now be completed by slipping the PCB into the case and securing it to the base of the case using four No.4 × 6mm self-tapping screws. These go into matching integral mounting pillars in the case. You will also have to fit the battery snap connector (see text) and the front panel label (Fig.9).



Above: this is the view inside the completed pocket version but without the battery snap fitted. Note the corner cutouts in the PCB at the top, to clear the case pillars.



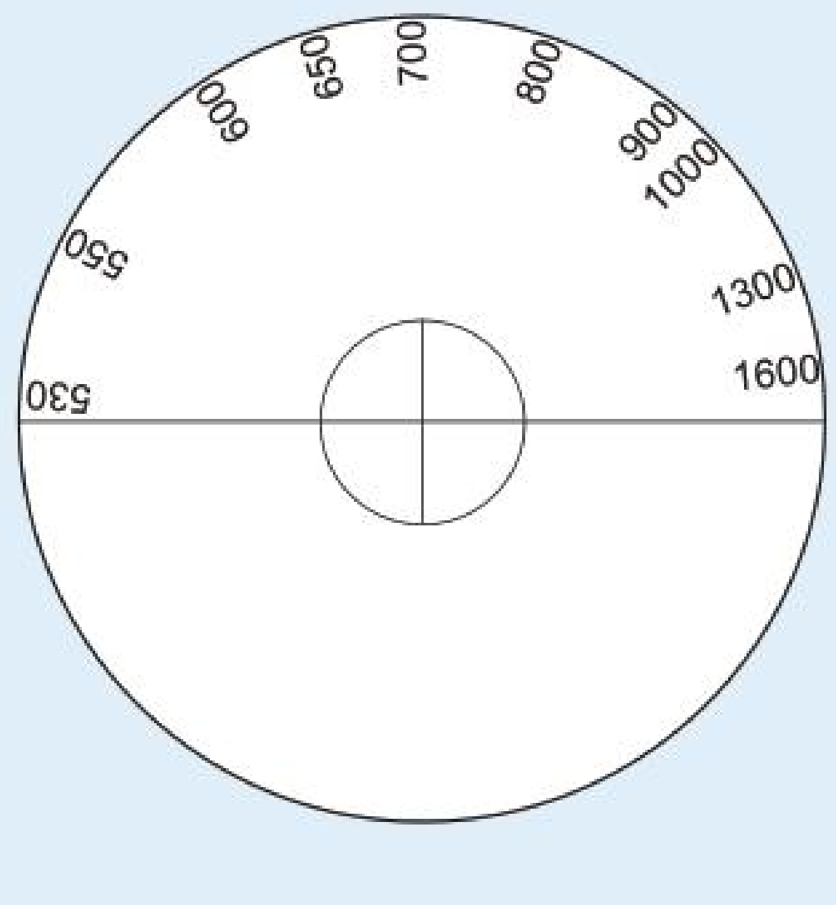
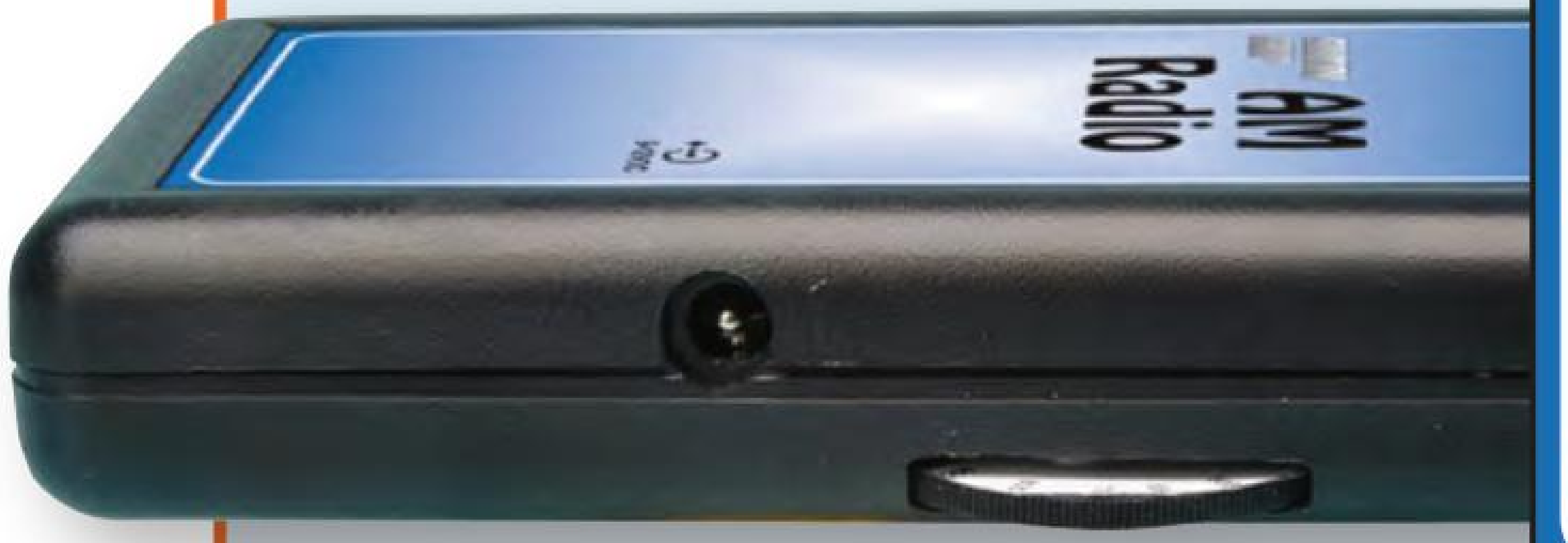


Fig.7 (above) shows the drilling template and control panel for the pocket version.

Fig.8 at right is the dial label for the thumbwheel that's supplied with VC1.



This edge view shows the slot for the tuning thumbwheel and the hole for the DC socket.

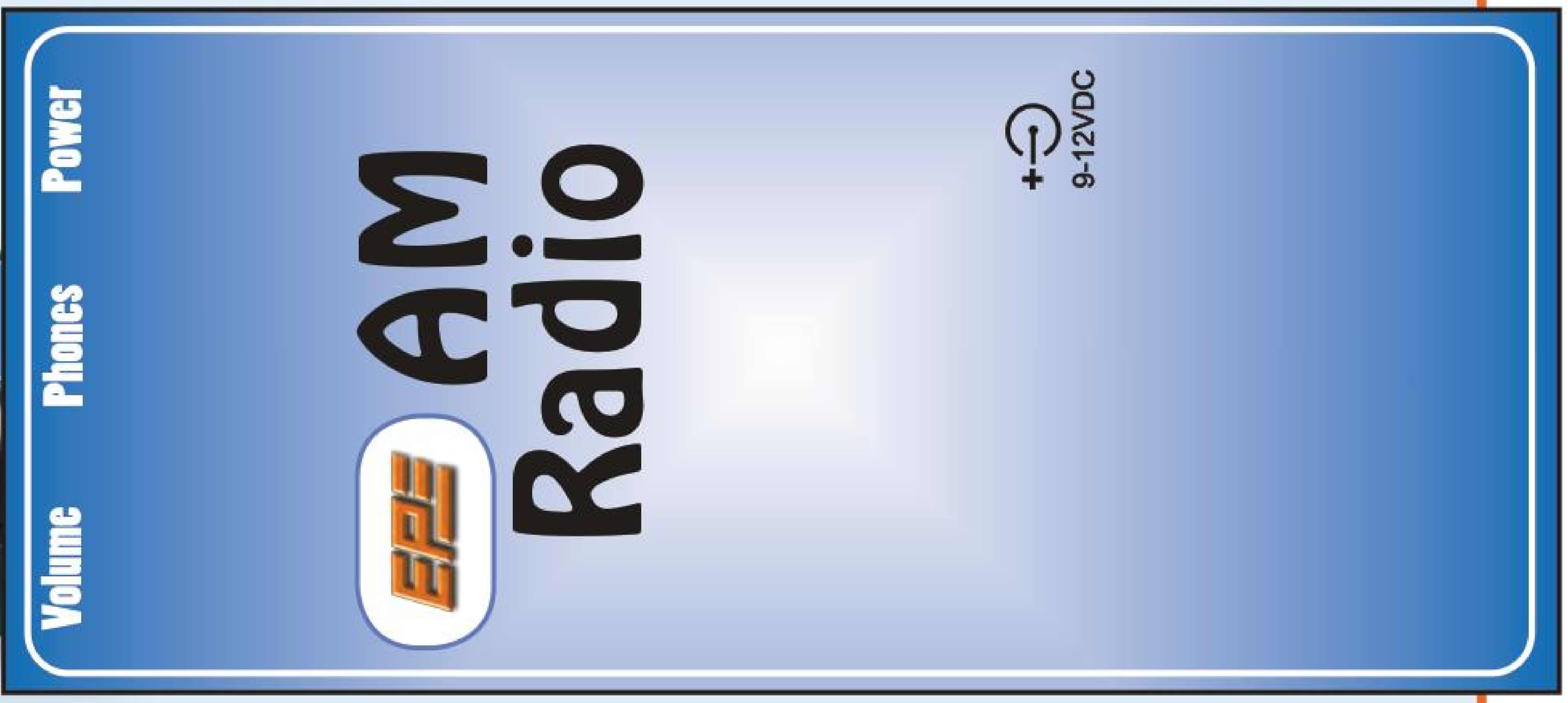


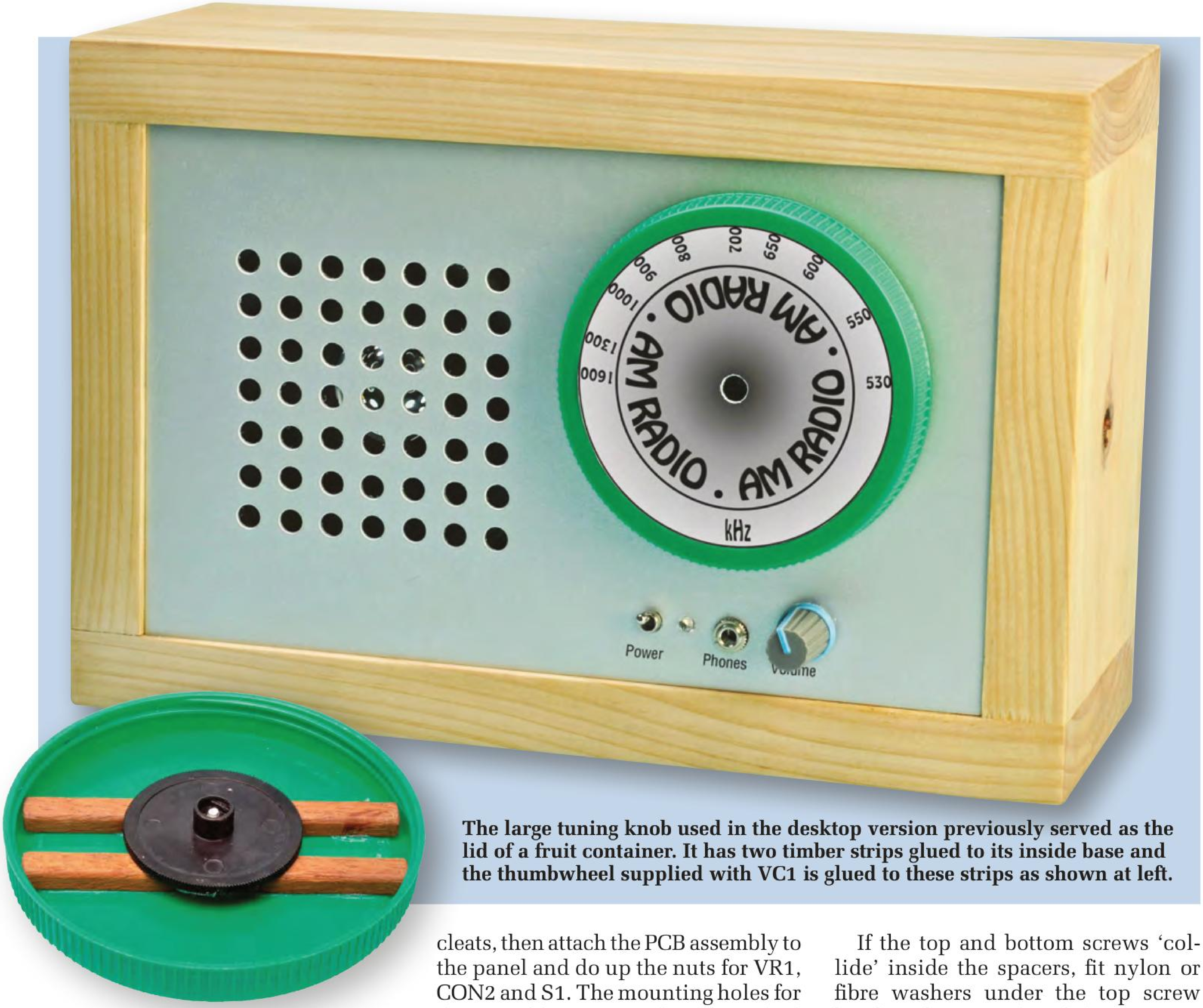
Fig.9: this is the full-size front panel label for the pocket version.

Desktop version assembly

The desktop version's case is built using a length of 800 × 90 × 19mm dressed pine. This is cut into two 238mm and two 120mm lengths and the pieces glued together using butt joints to make a frame (see photo).

A 200 × 120mm aluminium sheet (1mm thick) is used for the front panel. This panel is recessed by 3mm into the timber frame and attached by gluing its inside corners to cleats located at each corner.

Before attaching the aluminium panel, you have to drill the holes for



The large tuning knob used in the desktop version previously served as the lid of a fruit container. It has two timber strips glued to its inside base and the thumbwheel supplied with VC1 is glued to these strips as shown at left.

a loudspeaker grille, plus holes for the power switch, LED indicator, headphone socket and volume pot. Fig.4 shows the drilling template for the loudspeaker grille, while Fig.6 shows the front-panel label/drilling template (also available for download from the *EPE* website). Attach this template to the panel using double-sided tape, with its bottom edge aligned with the bottom of the panel, then drill the holes to the sizes indicated.

Variable capacitor VC1 is also mounted on the aluminium panel. It's just a matter of positioning it so that the 84mm-diameter tuning wheel that's used is clear of the controls and the speaker grille. You will have to drill and ream a 7mm clearance hole for VC1's shaft, plus two 2.5mm holes to accept its mounting screws.

Once all the holes have been drilled, glue the aluminium front panel to the cleats, then attach the PCB assembly to the panel and do up the nuts for VR1, CON2 and S1. The mounting holes for the rear of the PCB can then be marked on the wooden base (using the PCB mounting holes as a guide). Carefully measure the locations of these holes, then mark corresponding locations on the outside (bottom) of the case.

Before drilling these holes, remove the PCB assembly to avoid accidental damage. Once it's out, drill two 3mm holes right through the base at the marked locations and countersink these holes by 2mm using an oversize drill – just enough so that the heads of 3mm machine screws fit inside and do not protrude below the surface of the timber.

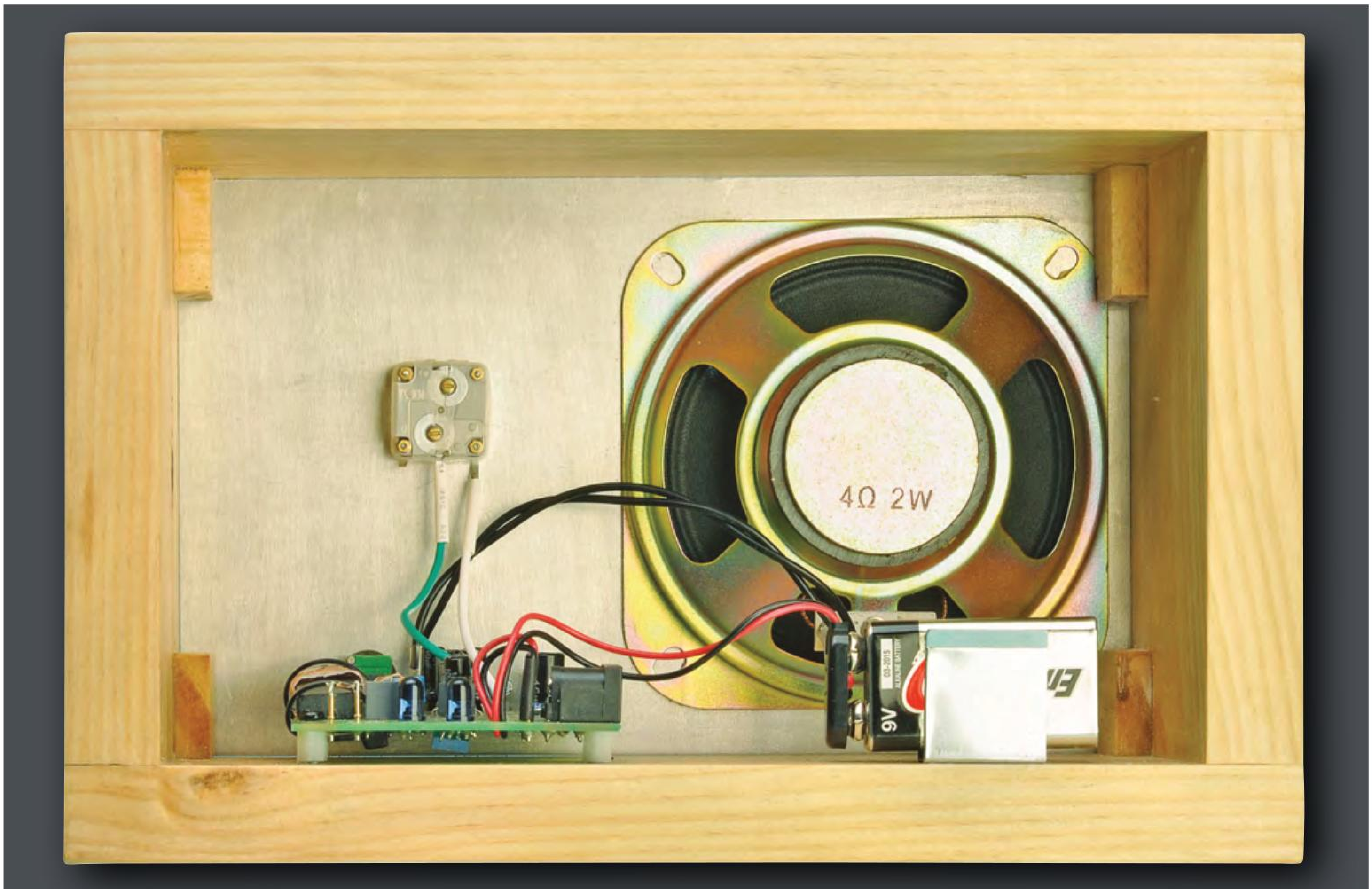
That done, the PCB assembly is refitted to the front panel and M3 × 6mm tapped nylon spacers are attached to its rear mounting holes using M3 × 5mm screws. These spacers are then secured to the timber base using M3 × 20mm machine screws fed up through the countersink holes.

If the top and bottom screws 'collide' inside the spacers, fit nylon or fibre washers under the top screw heads. Alternatively, if the countersinking is too deep, you can fit washers under the bottom screw heads (or you can shorten the 20mm screws).

Tuning capacitor VC1 can now be secured to the front panel using the two M2.5 × 3mm machine screws supplied. It's then fitted with its tuning wheel. For our prototype, we used an 84mm-diameter tuning wheel that previously served as the lid of a plastic fruit container. The small thumbwheel supplied with VC1 is attached to the inside of this lid by first gluing two parallel 4mm-high × 6mm-wide timber strips either side of centre and then gluing the thumbwheel to these using silicone adhesive, as detailed below.

Centring the thumbwheel

It's vital to correctly centre the thumbwheel inside the lid. This is done by first drilling a small pilot hole through the centre of the lid, then enlarging



This is the view inside the completed desktop version. The rear of the PCB rests on M3 × 6mm tapped spacers which are secured using machine screws. You can either use silicone to secure the aluminium panel to the internal cleats or you can drill holes at the corners and fasten the panel to the cleats using small wood screws.

this hole to about 4mm using a tapered reamer. It's then just a matter of visually lining up the centre of the thumbwheel with this hole when the thumbwheel is glued in place.

Be sure to attach the thumbwheel with its collar facing outwards.

You should now wait 24 hours for the silicone to set before attaching the tuning wheel to VC1's shaft. The centre hole through the lid provides access to the thumbwheel screw.

Dial label

Fig.5 shows the dial label and this is also available in PDF format from our website. Before affixing it to the lid, rotate the tuning wheel to its centre position. The dial label can then be glued in place with the 'kHz' marking at the bottom.

A sharp hobby knife can be used to cut out the centre hole to provide access to the thumbwheel screw should this later become necessary.

Final wiring

The loudspeaker can now be fitted and the wiring run to it and to tuning capacitor VC1. In our case, we used a smear of silicone sealant at each corner to secure the speaker to the rear of the aluminium panel. Alternatively, you could drill mounting holes through the panel and secure the speaker using M4 × 10mm machine screws, washers and nuts.

You will need to connect the two leads from the PC stakes at the front of the PCB to the speaker. Another two leads run from the PCB to VC1. Note that the centre terminal of VC1 must go to the ground connection (ie, the centre terminal for VC1 on the PCB).

Finally, the battery clip holder can be secured to the base using a wood screw. It's optional, however – leave it out if you intend to only power the unit from a plugpack supply.

Testing

To test the unit, apply power and check that LED1 lights when S1 is switched on. If it doesn't, check that the supply leads are the correct way around and that diode D1 and LED1 are oriented correctly. Check also that Q1's emitter is at about 1.4V.

If everything is correct, monitor the output (ie, via headphones or the loudspeaker) and tune in a station. When you find one, adjust trimpot VR2 for best sound quality (ie, for minimum distortion and noise). This trimpot sets the operating voltage at IC1's input so that it operates correctly, without high-frequency oscillation or distortion which can occur if VR2 is adjusted too far clockwise.

On the other hand, adjusting VR2 too far anticlockwise can result in excess noise.

The next step is to make some simple alignment adjustments, so that the receiver covers the correct tuning range. First, if there's a local station at the low-frequency end of the dial (ie, close to 530kHz), check if the station can be tuned in. If it cannot, it will be necessary to adjust the set to give a lower minimum tuning frequency and that's done by sliding the coil towards the middle of the ferrite core.

Parts List

1 PCB, available from the *EPE PCB Service* code 06101121, 64mm × 86mm
1 9V battery
1 9V battery clip lead
1 miniature PCB-mount SPDT toggle switch (S1)
1 10kΩ log potentiometer, 9mm square, PCB-mount (VR1)
1 100kΩ horizontal miniature trimpot (VR2)
1 knob to suit volume pot
1 switched 2.5mm PCB-mount DC socket (CON1)
1 PCB-mount 3.5mm stereo socket (CON2)
1 DIP8 IC socket (optional)
1 tuning coil with ferrite rod (L1) (Jaycar LF1020)
1 tuning capacitor 60-160pF (VC1)
2 100mm cable ties
8 PC stakes

Semiconductors
1 MK484 single chip AM radio (IC1) OR 1 TA7642 single chip AM radio (IC1)
1 LM386N amplifier (IC2)
1 BC547 NPN transistor (Q1)
1 3mm high-brightness red LED (LED1)
2 5mm IR LEDs (LED2,LED3)
1 4.7V 1W Zener diode (ZD1)
1 1N5819 1A Schottky diode (D1)
1 1N4148 diode (D2)

Capacitors
2 470µF 16V PC electrolytic
2 100µF 16V PC electrolytic
2 10µF 16V PC electrolytic
3 100nF MKT polyester
1 47nF MKT polyester
1 18nF MKT polyester
1 10nF MKT polyester
1 470pF ceramic

Resistors (0.25W, 1%)
1 100kΩ
1 27kΩ
1 6.8kΩ
1 2.2kΩ
2 1kΩ
2 10Ω

Extra parts for desktop version

1 aluminium panel 200mm × 120mm × 1mm
1 90 × 19 × 800mm length of timber (pine or similar)
1 100mm 4Ω loudspeaker
1 84mm diameter tuning dial (eg, the lid from a plastic fruit container)
1 dial label, 71mm diameter
1 9V battery clip
1 wood screw to secure battery holder
2 M3 × 5mm screws
2 M3 × 20mm screws
2 M3 × 6mm tapped standoffs
1 100mm length of green light-duty hook-up wire
1 100mm length of white light-duty hook-up wire
1 200mm length of black light-duty hook-up wire

Extra parts for pocket version

1 remote control case 135 × 70 × 24mm
1 front panel label, 50 × 114mm
2 2.5mm spacers (eg TO-220 insulating bushes)
2 M2.5 × 6mm screws
4 M3 × 6mm screws or No.4 × 6mm self-tapping screws

Alternatively, to obtain a higher minimum frequency (eg, if stations close to 530kHz are coming in too early in the band), slide the coil towards the end of the ferrite rod. The waxed paper end of the coil former may need to be trimmed if the coil needs to be positioned slightly past the end of the ferrite rod, but be careful not to cut the wires.

Now tune to a station at around 1600kHz (if possible). The upper tuning frequency can then be adjusted using the padder capacitor adjustment screw at the rear of VC1 (the one closest to its output pins).

If you don't have stations available at the two frequency extremes (or close to them), then adjust the ferrite rod coil and padder screw so that the stations tune in at the indicated positions on the dial. It's just a matter of adjusting the coil for stations at the low-frequency end of the dial and the padder screw for stations at the high-frequency end until the best compromise is achieved.

Finally, for a full list of AM broadcast stations in the UK see: **http://en.wikipedia.org/wiki/List_of_radio_stations_in_the_United_Kingdom**

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Which direction for the connected car?

Mark Nelson

Pundits declare that the connected car market worldwide will be worth £31 billion in 2018, along with an almost sevenfold increase in the number of new cars equipped with factory-fitted mobile connectivity over the next five years. This will provide valuable safety and security features, as well as infotainment and navigation services. Marvellous news – or potentially perilous? Mark Nelson lifts the bonnet on the issues.

BUT WHAT IS A CONNECTED car actually? If you take the sober definition offered on Wikipedia, it is 'a car that is equipped with Internet access, and usually also with wireless local area network. This allows the car to share Internet access to other devices both inside and outside the vehicle.' Often, it continues, the car is also provided with special technologies that provide additional benefits to the driver, such as alerting you if you exceed the speed limits or automatic notification if your car is involved in an accident. Connected cars are also benefitting from new smartphone apps that interact with your vehicle from any distance to unlock your car, find its location or check its battery status (important for electric cars).

Battle for the money

You won't be surprised to learn that there's serious money to be made from the rise of the connected car, or that there's a battle between manufacturers to set the definitive standards for interconnecting user devices to the connected car. Earlier this year the formation was announced of the Open Automotive Alliance, a global alliance of tech-stuff and car industry leaders committed to promoting the Android platform in cars. Members include Audi, GM, Google, Honda, Hyundai and chip maker Nividia. CarPlay is a purely Apple initiative to connect iPhone 5/5c/5S devices to car infotainment units using iOS 7 to cars using Apple's Lightning connector (*not* a lightning conductor!).

Trailing behind somewhat, Microsoft announced its (concept-only) plans for the connected car, based on the Windows operating system (I bet you can guess what I am thinking – so there's no need to put it into words!). Apparently, it will connect with Windows Phone 8.1 to enable users to make telephone calls, play music and more, although hopefully in a hands-free manner that doesn't divert their eyes from the road ahead. To quote a respected trade journal, 'Microsoft has a lot of ground to make up in the connected vehicle market, but it does have some tricks up its sleeve'. Having bought Nokia's mobile handset business, the conglomerate is investing some £59 million into this new market.

Deadly downside

If Microsoft is able to guarantee unconditionally the integrity of its Windows operating system when applied to a motor vehicle, then we have nothing to fear, but the potential for other kinds of disaster must still be considered with great care. If there is any possibility for the connectivity provided in connected cars to communicate with the vehicle's Engine Control Unit (ECU), then be very afraid. In the USA two 'white hat' hackers now funded by the US government have demonstrated how they hijacked a Ford Explorer and a Toyota Prius wirelessly (**http://www.forbes.com/sites/andygreenberg/2014/04/08/darpa-funded-researchers-help-you-learn-to-hack-a-car-for-a-tenth-the-price/**). And if you read my October 2013 article you will remember the tale of the American 'gadfly' journalist Michael Hastings, who was killed when his 2013-model Mercedes-Benz C250 went out of control. At the time, a former chief counter-terrorism adviser stated that Hastings' death was 'consistent' with a cyber-attack on his car, adding that not only does the technology to hack cars exist, but 'there is reason to believe that intelligence agencies for major powers, like the United States, are already equipped to stage such an attack.'

Hack attack

Modern cars are potentially easy to hack in this way because they employ an ECU to manage engine power, transmission and braking. 'Hardware hackers' have already demonstrated a device costing £16 to make that can bypass the security encryption of ECUs. This gizmo currently needs to be installed on the target car, but the next version will be wireless. Right now we are still in the 'spark transmitter' or 'crystal set' stage of development, but leading antivirus software supplier Kaspersky Lab reckons we need to take this threat entirely seriously (**http://blog.kaspersky.com/car-hacking/**).

Suspect science

If you are bombarded with the 'you must see this' type of e-mails from your techie friends, you will probably have seen the following filmlet already: **http://sixtysymbols.com/videos/car_key.htm**

It's all about extending the distance from which you can unlock your car using the electronic key and endearingly the e-mail states: 'Might not be useful to you because you don't drive, but if you share it with those important people who do, they will love you more for it.' I'll do anything to get people to love me, so what's it all about? Well, Professor Roger Bowley, who is 'a popular lecturer and respected theoretician' at the University of Nottingham purports to show how he unlocks his car from various distances, using waves from his key, brain and a big bottle of water. I imagine this was made as an April Fool's Day spoof, as I have never seen such (amusing) drivel in my life.

I confess I am not a professor and I learned radio the hands-on way. My knowledge of radio theory extends as far as a City & Guilds certificate and passing the radio amateur exam, but as far as I know, the human brain is unable to amplify radio signals. I suspect the reason why this trick appears to increase the range is because at different stages of the experiment the professor inadvertently changes the polarisation of the signal from horizontal to vertical (or vice versa). You see him do this if you watch closely. Also, sometimes he holds the key fob broadside, at other times in line with the blade. No consistency at all. Practical tests confirm that orienting the key into a vertical position makes a significant difference.

If you look on the Internet you will find other people making very similar 'discoveries' and plenty of discussion, ill-informed and totally unscientific in the main.

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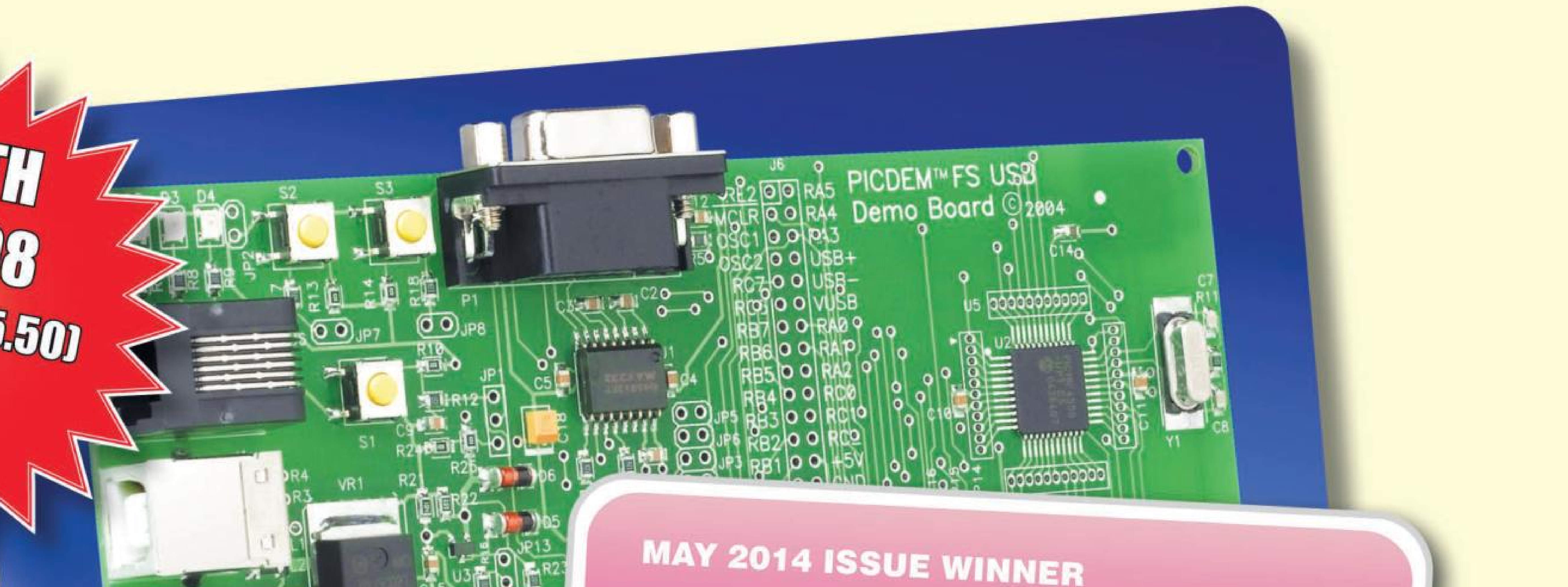

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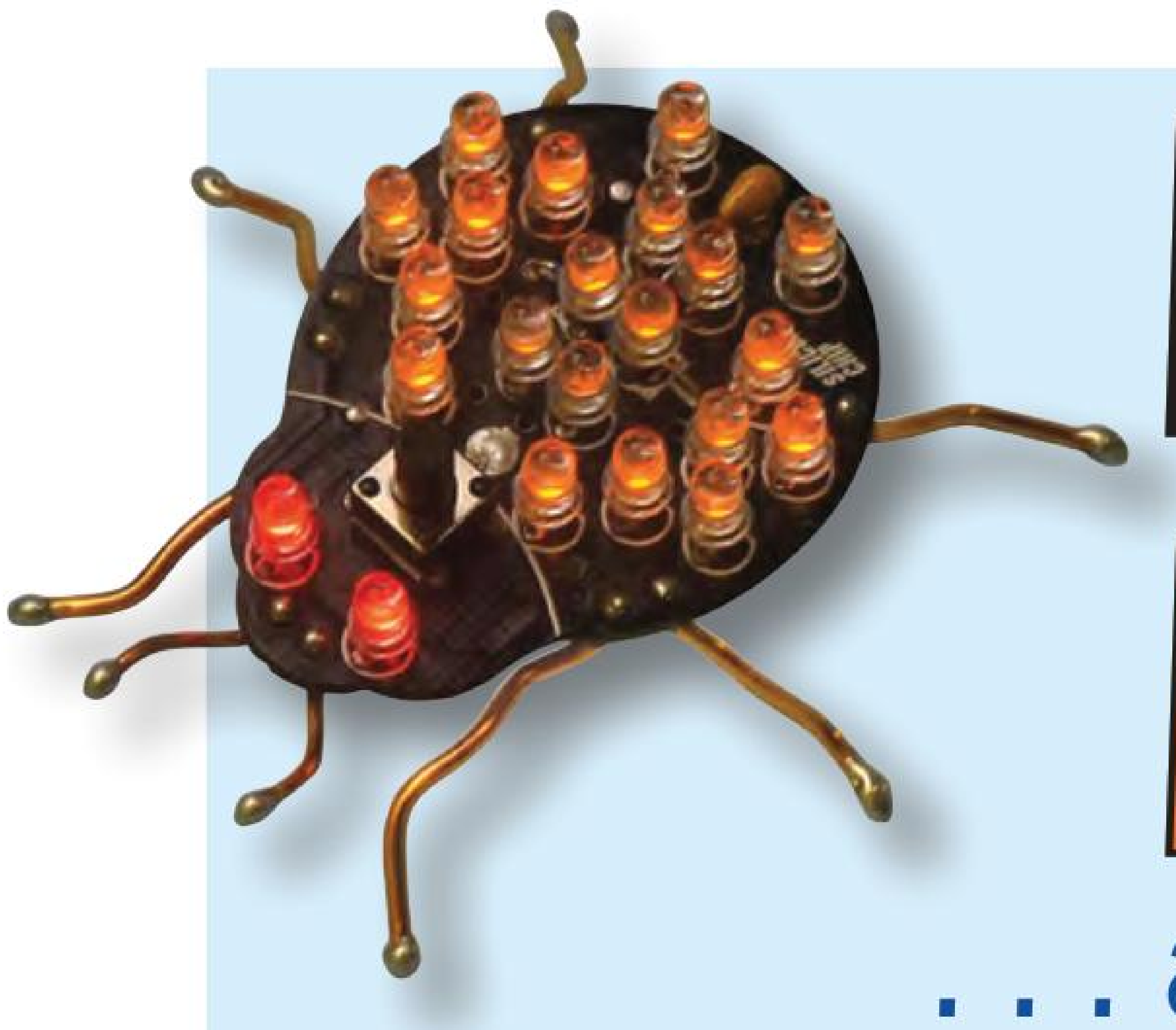
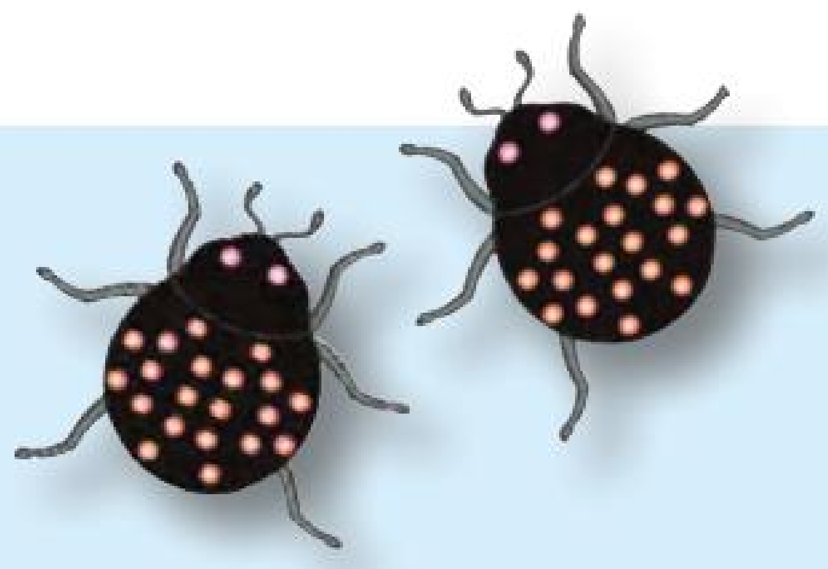


LED LADYBIRD



By JOHN CLARKE

. . . an eye-catching electronic beetle

Be the light of the party with this unique electronic brooch – or just build it as an interesting novelty piece

Tired of lacklustre fake precious-stone brooches and ornaments that have no life? Why not build a vibrant electronic brooch or ornament instead? *LED Ladybird* uses high-brightness LEDs for its eyes, wings and abdomen, and it flashes these in a fetching moving pattern.

IF YOU ARE AFTER something different to wear at a party or dance, it's hard to look past the *LED Ladybird*. Suitably fitted with a clasp, you could wear it as a brooch, or you could attach it to a headband or maybe even use it as an earring or pendant.

Perhaps you could just build it as a fascinating coffee table piece, a school project or an executive toy. Apart from that, it's a great little project for honing your 'surface-mount' assembly skills.

So why have we called it an *LED Ladybird*? Well, first, because it's shaped like a real ladybird and second, because it incorporates LEDs! We've taken a few liberties with the colours though. A real ladybird has an orange body with black spots, but that's impractical for our electronic version because there are no black LEDs.

So, we reversed the colours, using a black PCB to make up the body and 20 orange LEDs for the spots. Two high-brightness red LEDs are used for the eyes.

We're not too sure what colour eyes a real ladybird has, but red looks pretty good in our opinion. Besides, they needed to be different to the orange LEDs used for the spots.

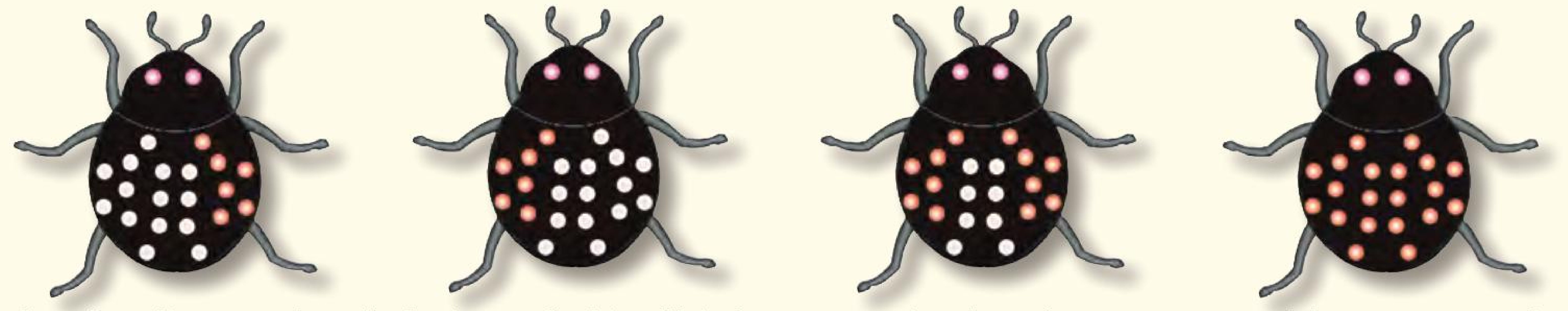
As shown in the photos, the PCB's outline matches the shape of a real ladybird beetle; ie, it's roughly pear-shaped. Along with the LEDs, we've also fitted six wire legs and two antennae to the PCB, to make it more ladybird like. There's also a pushbutton switch to turn it on or off and it's all powered from a single 3V lithium cell slung underneath the insect's belly.

LED sequence

When you turn it on, the LEDs flash in an intriguing and fascinating sequence. This sequence is designed to mimic the flapping of a ladybird's wings, from take-off to landing.

First, the two red eyes come on one after the other (and stay on), then the eight central LEDs (six abdomen and two rear) flash once in a chaser sequence. Once that's completed, the six orange LEDs making up the righthand wing begin flashing, slowly at first then gradually increasing in speed before slowing down again.

These six right-wing LEDs then extinguish and the six left-wing LEDs repeat the sequence, after which both sets of wing LEDs flash together. The eight central LEDs then get in on the act, two at time, with all LEDs on the



These four diagrams show the basic LED flashing (flying) sequence. First the red eyes come on and the orange LEDs for the right wing flash. The left wing then flashes, then both wings and then all the LEDs flash, including those down the middle. In practice, it's a bit more complicated than that, so take a look at the video on our website (see text).

beetle (including the eyes) then flashing together.

After that, there's some more fancy footwork with the eight central body LEDs entering a chase sequence while the other LEDs all flash at a rapid rate. The unit then goes into a power-down sequence with the central LEDs going out, and the wing LEDs flashing at a decreasing rate until they extinguish.

Finally, the eight trail LEDs and the red eyes flash once in a chaser sequence, from rear to centre, after which the two eyes extinguish and the unit automatically powers down.

Alternatively, you can switch the unit off at any time while it is operating by pressing the power switch.

Of course, it's far more interesting when you see it in action. So don't just rely on the written description. Instead, take a look at the video at: **siliconchip.com.au/videos/ledladybird**

Continuous party mode

Normally, the LED Ladybird runs through a single cycle of its entire LED lighting sequence and then automatically switches off to save power. It can be run again at any time simply by pressing the pushbutton power switch.

Alternatively, it can also be set up to continuously repeat its LED lighting repertoire until switched off with the pushbutton switch. This continuous mode setting is ideal if you want to wear the LED Ladybird to a party or use it as a display in a shop window or on a Christmas tree.

Switching the unit to operate in continuous mode is easy – just hold the pushbutton switch down for several seconds when switching on, until the right eye blinks off briefly.

We estimate that the lithium cell will last for about 10 hours when the unit is operated in continuous mode. If you require longer than this, then the unit can be powered from two AA cells (or any other external 3V supply) connected via a length of twin cable.

Circuit details

Take a look now at Fig.1 for the circuit details. It's really very simple and uses an 18-pin PIC microcontroller (IC1), 22 LEDs and not a lot else. All the clever stuff is hidden inside the microcontroller, which is programmed to control the LEDs.

As shown, the 3V supply rail (from a lithium cell or two AA cells) is bypassed with a 1µF ceramic capacitor. Diode D1

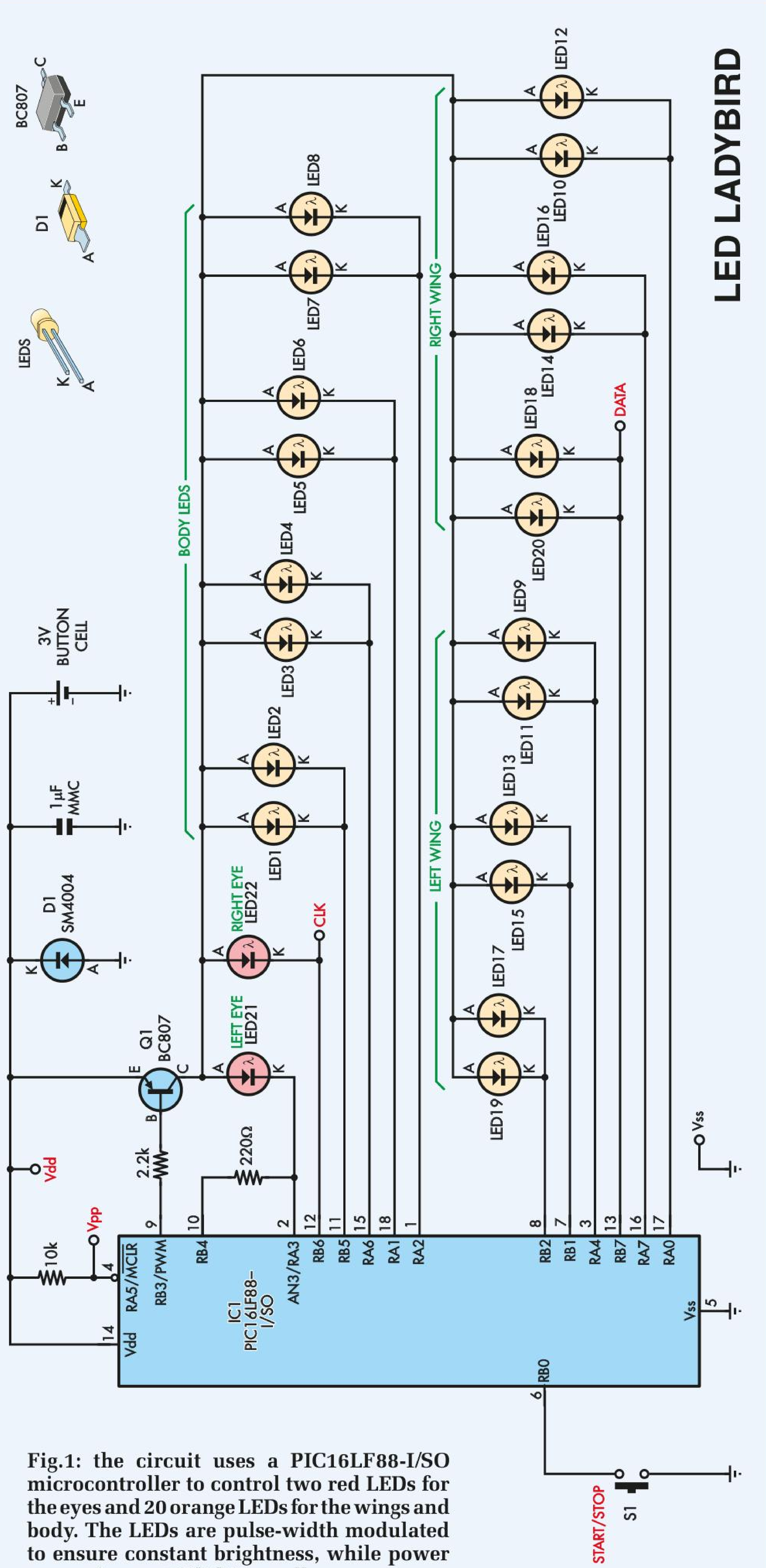

LED LADYBIRD
BC807
B
E
C
D1
K
A
LEDS
3V BUTTON CELL
1µF MMC
D1 SM4004
Q1 BC807
Vdd
2.2k
220Ω
10k
Vpp
LEFT EYE LED21
RIGHT EYE LED22
CLK
BODY LEDS
LED1
LED2
LED3
LED4
LED5
LED6
LED7
LED8
RIGHT WING
LED12
LED10
LED16
LED14
LED18
LED20
DATA
LEFT WING
LED9
LED11
LED13
LED15
LED17
LED19
IC1 PIC16LF88-I/SO
RA5/MCLR
RB3/PWM
RB4
AN3/RA3
RB6
RB5
RA6
RA1
RA2
RB2
RB1
RA4
RB7
RA7
RA0
RB0
Vdd
Vss
14
4
9
10
2
12
11
15
18
1
8
7
3
13
16
17
5
6
Vss
START/STOP
S1

Fig.1: the circuit uses a PIC16LF88-I/SO microcontroller to control two red LEDs for the eyes and 20 orange LEDs for the wings and body. The LEDs are pulse-width modulated to ensure constant brightness, while power comes from a 3V lithium cell.

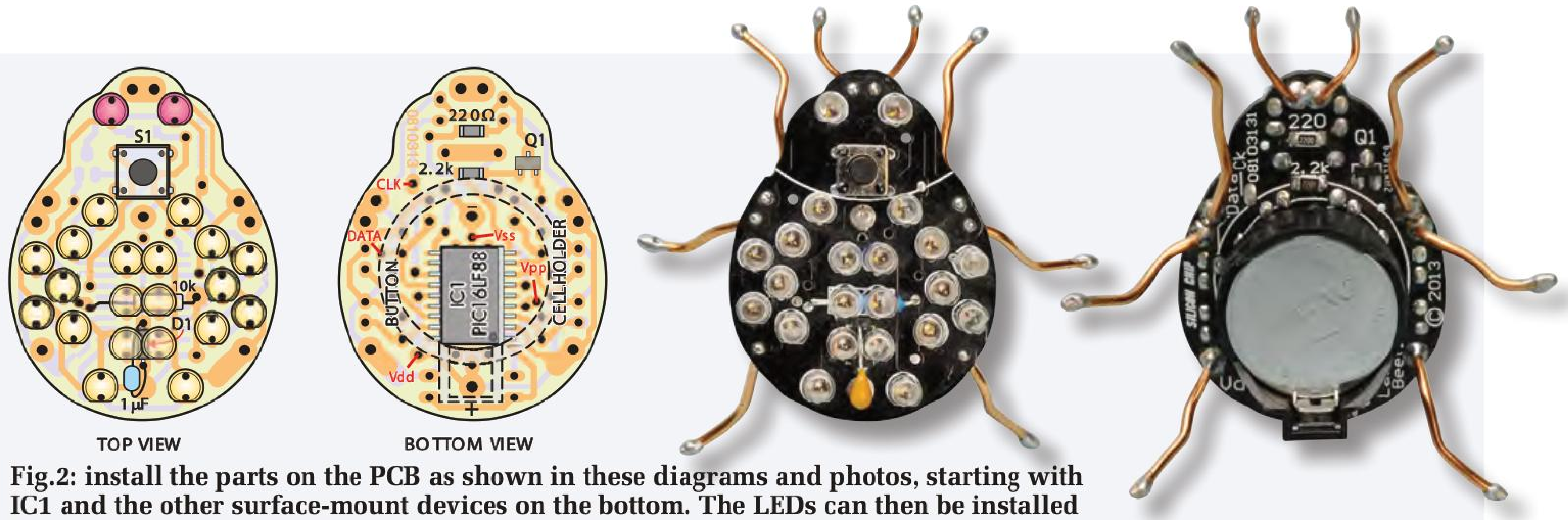
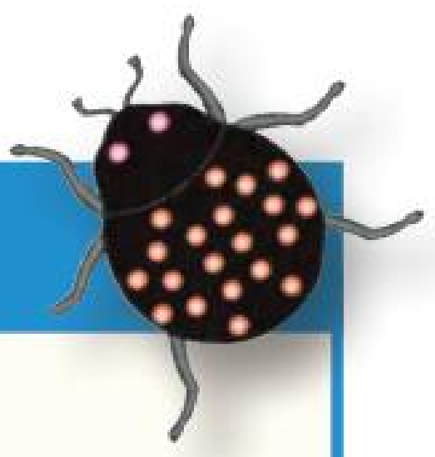


Fig.2: install the parts on the PCB as shown in these diagrams and photos, starting with IC1 and the other surface-mount devices on the bottom. The LEDs can then be installed on the top, then the cell holder on the bottom and finally switch S1 on the top.

Parts List



1 PCB, available from the *EPE PCB Service* code 08103131, 43 × 32mm (with black solder mask)
1 SPST vertical mount micro-switch with 6mm actuator (S1)
1 20mm button cell holder
1 CR2032 lithium cell
1 200mm length of 1.25mm enamelled copper wire
1 40mm length of 1mm enamelled copper wire

Semiconductors
1 PIC16LF88-I/SO microcontroller programmed with 0810313A.hex (IC1)
20 3mm orange LEDs, 1700mcd (LEDs1-20)
2 3mm red LEDs, 1000mcd (LED21,LED22)
1 BC807 (SOT-23) surface-mount PNP transistor (Q1)
1 SM4004 1A diode (D1)

Capacitors
1 1µF MMC

Resistors (0.25W, 1%)
1 10kΩ axial lead
1 2.2kΩ SMD 1206 (3216 metric)
1 220Ω SMD 1206 (3216 metric)

Alternative external 3V supply
1 SM5404 3A diode or use an axial-lead 1N5404 across the supply (D1)
1 dual AA-cell battery holder
2 AA cells
1 length light-duty figure-8 wire

provides reverse polarity protection – it conducts and limits the voltage applied to IC1 to just –0.6V should the supply be connected in reverse. This diode is a 1A type for use with a 3V lithium cell, but it should be upgraded to a 3A type if using an external supply (see parts list).

Note that a Schottky diode should not be used here. These have significant reverse leakage and would draw tens of microamps continuously from the cell, flattening it prematurely.

IC1, a PIC16LF88-I/SO, is a surface-mount SOIC low-power version of the PIC16F88. This device can operate down to just 2V. Diode D1, transistor Q1 and the 2.2kΩ and 220Ω resistors are also all surface-mount devices.

IC1's $\overline{\text{MCLR}}$ input (pin 4) is tied to the +3V supply rail via a 10kΩ resistor, so that the micro resets at power-on. Pin 14 (Vdd) of the micro connects directly to the +3V rail, while on/off switch S1 connects between its RB0 input (pin 6) and ground. This RB0 input is normally pulled high to the +3V supply rail via an internal pull-up resistor, but is pulled low each time S1 is pressed.

Normally, IC1 is asleep, with its internal oscillator stopped and the microcontroller section not running. This places IC1 in its lowest current draw state. It typically draws 100nA in this mode, but we measured just 11nA for our prototype.

Pressing S1 pulls RB0 (pin 6) low. This wakes IC1 and starts the software running. Pressing the switch while IC1 is running places it in sleep mode gain.

LEDs1-22 are driven directly by IC1's output ports, without current-limiting resistors. This was done both to save on the parts count and because there's no space for current-limiting resistors on the PCB.

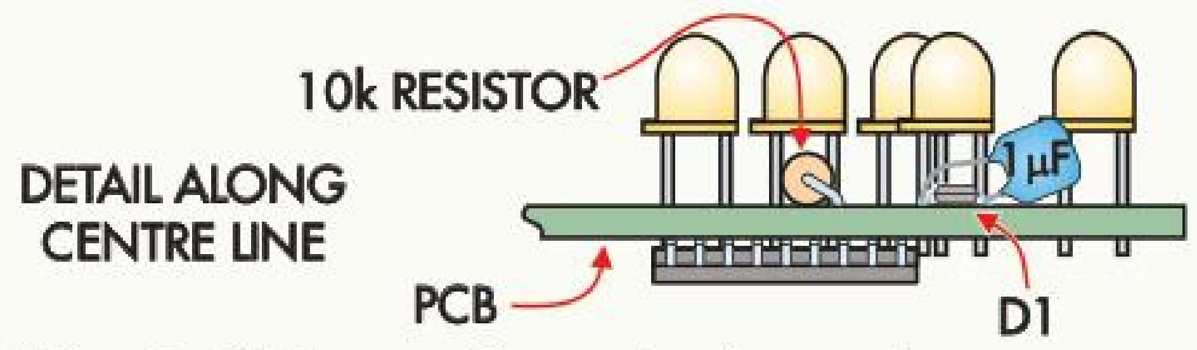


Fig.3: this sectional view shows how the 1µF capacitor is installed at the rear of the PCB, with one lead routed over the top of D1.

Driving the LEDs in this way is quite acceptable provided we don't cause too much current to flow in the output pins. In this circuit, the maximum supply voltage is around 3.3V (with fresh cells) and this prevents each output from sinking more than about 21mA. This is within the limits allowed for both the microcontroller's output pins and for the LEDs.

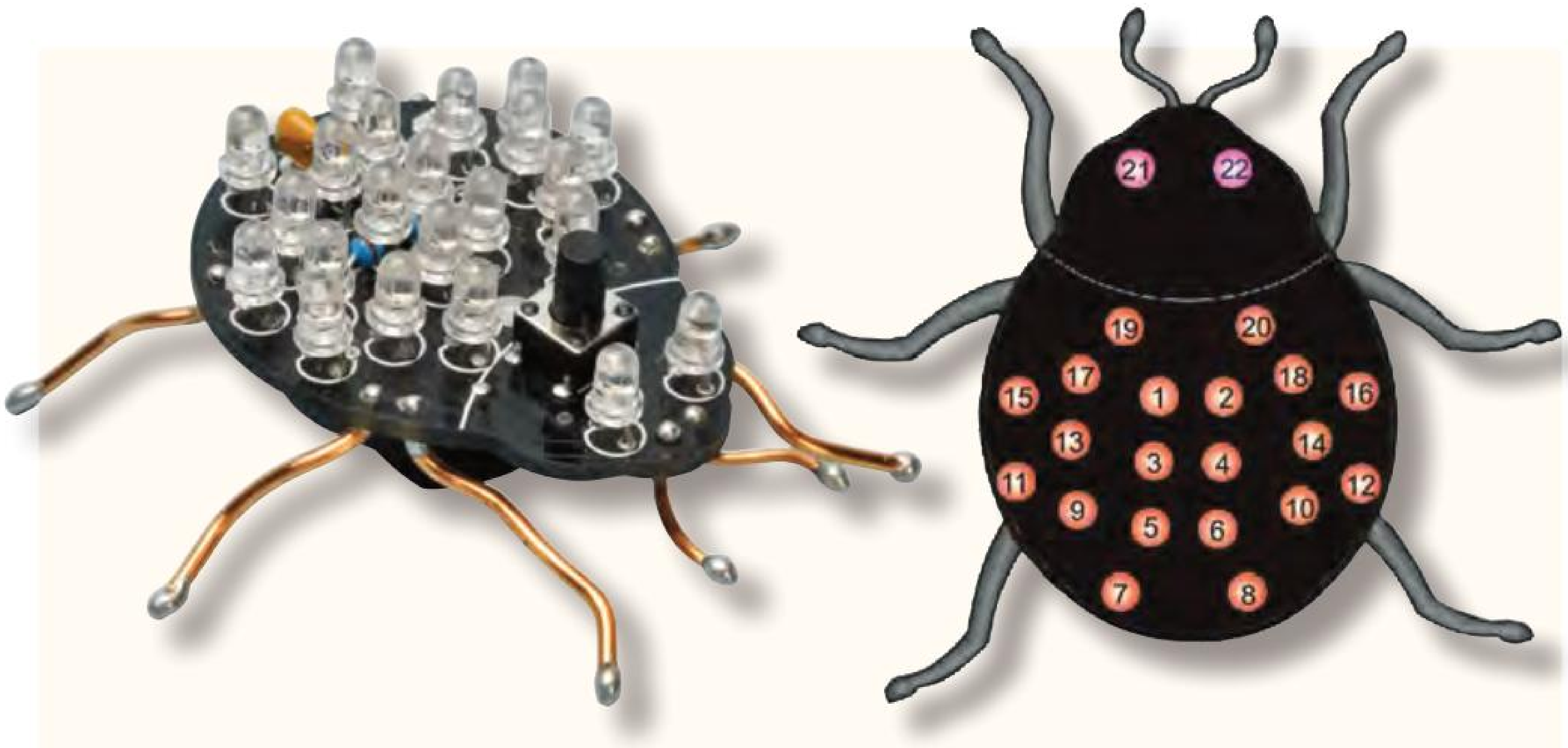
How do we arrive at that figure? Well, the impedance of the output pins is typically 70Ω and there will be 1.8V across each LED when it is on. This means that, with a 3.3V supply, the voltage across the 70Ω output impedance will be 1.5V, so the current through the LEDs will be 1.5V ÷ 70Ω = 21mA.

As the cell voltage falls, so does the LED current. For example, at a cell voltage of 2.2V and with 1.8V typically across the LEDs, there is just 0.4V across the 70Ω output impedance and so the current is just 5.7mA.

That means that the average LED current and hence the LED brightness would be dependent on cell voltage unless steps are taken to prevent this. So, to maintain a constant LED brightness independent of cell voltage, the LEDs are driven with a variable pulse width modulated (PWM) supply.

In this circuit, the LEDs are switched on and off at a 1kHz rate, with the duty cycle varied to provide constant brightness. At a 50% duty cycle (ie, LEDs switched on and off for equal periods), the average LED current is half that compared to a 100% duty cycle (ie, LEDs switched on all the time). So by varying the duty cycle, we can control the average current through the LEDs.

IC1's PWM output is at pin 9 and this drives PNP transistor Q1. This transistor in turn switches the supply to all the LEDs which have their anodes wired in parallel. This means that the supply to the LEDs switches off each time the PWM signal goes high (Q1 off) and switches on when the PWM signal goes low (Q1 on). The duty cycle is set to produce consistent LED brightness over the cell voltage range from 2 – 3.3V.



Above: another view of our prototype LED Ladybird, along with a diagram showing the LED numbering scheme (right).

Measuring cell voltage

In order for IC1 to correctly vary the PWM signal, it needs to accurately measure the cell voltage. That's done indirectly by first switching Q1 fully on and taking IC1's RB4 output (pin 10) low to drive LED21 via a 220Ω resistor. The resulting voltage across the 220Ω resistor is then measured by IC1's AN3 analogue input (pin 2) and this is then used to calculate the correct PWM duty cycle to drive the LEDs.

This measurement is made at the start of each LED flashing (or flying) sequence (ie, when power is applied or at the start of each sequence if the unit is operating in continuous mode) .

Once this measurement has been made, the RB4 output is set as an input, AN3 is set to an output and the PWM signal operates at the required duty cycle. That way, LED21 can now be driven directly by the PWM voltage at Q1's collector and RA3 (ie, the 220Ω resistor is taken out of circuit). This LED is on when RA3 is set low, while the other LEDs turn on when IC1 sets their respective outputs low.

Note that while the two eye LEDs are driven independently, the remaining LEDs are driven as sets of two in parallel. When the circuit is running and flashing the LEDs, the current drawn from the cell averages out at about 8mA.

Building it

OK, let's put *LED Ladybird* together. As shown in Figs.2 and 3, all the parts are mounted on a PCB which is available from the *EPE PCB Service*, coded 08103131 and measuring 43 × 32mm.

Start by checking the PCB for any faults such as shorted tracks and undrilled holes. The PCB supplied by the *EPE PCB Service* is double-sided, plated through, solder masked and screen printed. These are high-quality boards and are unlikely to have any defects – but it's always a good idea to check.

Having checked the board, begin the assembly by installing the surface mount parts on the underside – see Fig.2. IC1 should go in first. This is an 18-pin SOIC package and it's relatively easy to solder in place due to its 0.05-inch pin spacing. You will need a fine-tipped soldering iron, some solder wick and (preferably) a magnifying lamp to do the job.

The first step is to position the IC on top of its pads, making sure that it is oriented correctly. That done, solder pin 1 to hold it in place, then check to make sure that all the pins are correctly aligned with their pads. Adjust its position if necessary, then solder all the remaining pins, starting with the diagonally opposite pin (pin 10).

Don't worry if you get solder bridges between adjacent pins during this process; they are virtually inevitable. Once all the pins have been soldered, any bridges can be cleared by pressing solder wick against them using the hot tip of a soldering iron. This will soak up the excess solder while leaving the solder joint between the bottom of the pin and its pad intact.

The 2.2kΩ and 220Ω SMD resistors are installed next. It's just a matter of soldering these at one end first, then making sure they are correctly positioned before soldering the other ends. Once they're in, you can install SMD transistor Q1.

Now flip the PCB over and install the 10kΩ resistor. This is a conventional leaded part and it must be installed with its ends cranked slightly as shown in Fig.2. **This resistor must also be offset to the right, ie, the righthand lead must be bent close to the resistor's body.**

This is necessary to ensure that, when the LEDs are later installed, one LED's lead will straddle the central section of the resistor's body, while the leads of the adjacent LED to its left will be clear of the resistor end cap. That way, the LEDs that straddle this resistor will have their leads clear of the end caps – a necessary precaution to avoid possible short circuits.

Diode D1 (another SMD) can now go in. It must be installed with its cathode end towards the bottom edge of the PCB (ie, towards the rear of the ladybird). Once it's in, the next step is to install the 1µF MMC capacitor in parallel with this diode. This capacitor will need to have its leads bent so that it sits vertically between LEDs 7 and 8. The top lead is then run across the top of diode D1 (ie, between LEDs 5 and 6) and soldered to the diode end adjacent to the 10kΩ resistor.

You can now install the 22 LEDs. These must be fitted with their cathode leads (indicated by a flat edge on the LED bodies) oriented as shown. Start with the central LEDs, then work your way outwards, as this will make the job much easier.

These LEDs should all be stood off the PCB by about 3mm and this can be achieved by pushing each LED down onto a 3mm-high spacer before soldering its leads. Note that some of the centrally-located LEDs will have to have their leads soldered on the top side of the PCB, since IC1 prevents access to their pads on the underside.

The cell holder is next on the list. This sits against IC1 and must be orientated as shown in Fig.2 and the photos. Push it down onto the PCB as far as it will go before soldering its positive and negative pins. The positive pin is soldered from the underside of the PCB, while the negative pin is soldered from the top.

The parts assembly can now be completed by installing switch S1. This has to be left until last, otherwise it's too difficult to solder the adjacent negative pin of the cell holder.

In-circuit programming

Note that Fig.2 indicates the external connections for Vdd, Vss, Vpp, Data and Clock. These allow a PIC programmer to be connected if you want to program the PIC yourself with software downloaded from the *EPE* website (ie, before the battery holder is installed).

Alternatively, pre-programmed PICs for this project can be purchased from *EPE* and will also be supplied by kit suppliers.

Fitting the legs

The PCB assembly can now be completed by fitting the legs and antennae. Six 25mm lengths of 1.25mm-diameter enamelled copper wire are used for the legs, while 15mm lengths of 1mm wire are used for the antennae.

The first step is to straighten the 1.25mm-diameter copper wire by clamping one end in a vice and then pulling on the other end with a pair of pliers to stretch it slightly. That done, cut the wire into 25mm lengths, strip the enamel from both ends of each wire and solder them to the spare PC pads around the edge of the body.

The free end of each leg can then be covered with a solder blob, to form the feet. Once that's done, the two 15mm-long antenna can be fitted in similar fashion. The wires are then bent to shape using needle-nose pliers, as shown in the photos.

Check out

This is the easy part – simply insert a 3V lithium cell into the holder (positive side outwards) and check that the *LED Ladybird* works when switch S1 is pressed.

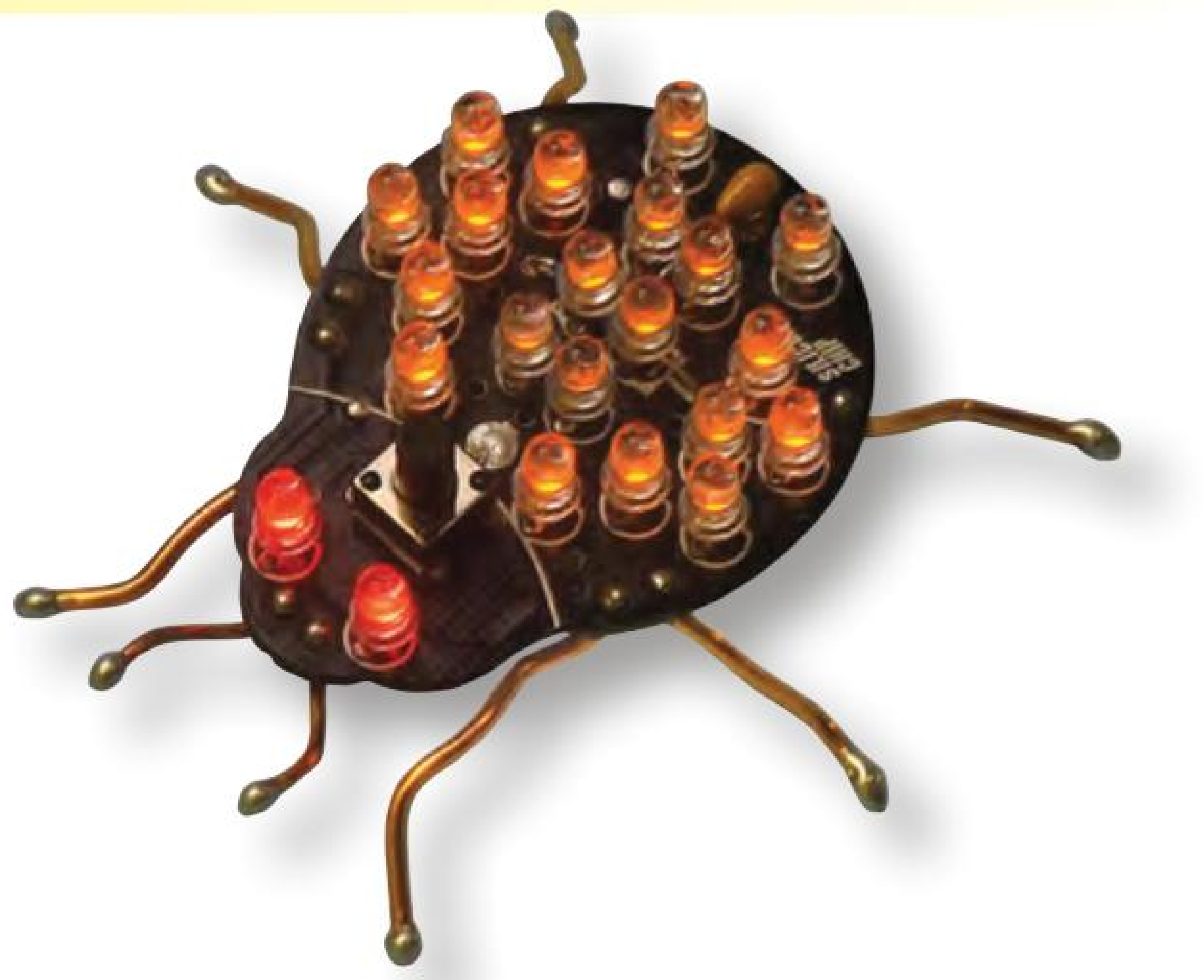
If it's working correctly, the left eye LED will appear to quickly come up to full brightness when the cell voltage is around 3V. As the cell voltage drops though, this LED will initially ramp up to a lower brightness before then jumping to full brightness.

Basically, this jump in brightness is small when the cell voltage is close to 3V, but gradually increases to a 50% jump in brightness as the cell voltage drops to 2V. This provides some indication of the cell's condition.

Once the LED's brightness has been set (ie, by the micro monitoring the cell voltage and adjusting its PWM signal), the right eye LED will come on and then the flashing LED sequence for the wings will start.

Single or repeat mode

As stated previously, the *LED Ladybird* is programmed to cycle through its LED flashing sequence just once, then automatically switch off. An entire cycle takes about 1 minute and 20 seconds (80s) but as mentioned, it can be stopped at any time by pressing S1.



If you want the LED sequence to cycle continuously, switch off, then press switch S1 and hold it down for several seconds until the right eye LED blinks off briefly. When you do this, the left eye LED will flash continuously (to indicate continuous mode) until S1 is released.

To go back to single-sequence mode, switch off, then press S1 and hold it down until the right eye flashes.

Attaching the LED Ladybird

The *LED Ladybird* can be easily attached to clothing with a strong rare earth magnet to 'clamp' the *LED Ladybird* in position.

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LifeSaver for Lithium or SLA batteries

Don't ruin an expensive SLA, Li-Ion, Li-Po or LiFePO$_4$ battery by over-discharging it. This small circuit will protect it by cutting off power before it reaches the danger zone. It has virtually no effect on available power or battery life. It's also ideal for preventing devices like uninterruptible power supplies and emergency lights from destroying their batteries in an extended blackout.

by Nicholas Vinen

Rechargeable lithium-based batteries are great – they have high capacity, long service life, high discharge current, are light weight and fast charging.

But they're easy to destroy if you run them down below a particular voltage level and in a lot of applications, all you have to do is leave the device on a bit too long and your expensive battery is lost.

Radio-controlled cars/planes/helicopters generally have a low voltage cut-out feature built in to the motor speed controller, but if you use these batteries in other applications, you definitely need this *Battery LifeSaver*.

As mentioned above, it's also suitable for use with most lead-acid batteries. As with most offices, factories and public buildings, we have quite a few emergency lights/exit signs in our office. While we only have the occasional black-out, we still have to replace several back-up batteries a year which really should have lasted a lot longer except that they were discharged to the point of death.

Features and specifications

- Works with sealed lead-acid, Li-ion, Li-Po and LiFePO4 batteries (6-24V)
- Very low quiescent current, <5µA
- Cut-out voltage adjustable from 5.25 to 25.5V
- High current-handling capability – 20A continuous, 30A peak (charge or discharge)
- 0.3-2V hysteresis, depending on battery type and voltage
- Very small PCB, to fit in tight spaces (34 × 18.5mm)
- Battery can be recharged once cut-out has engaged (maximum 1.5A)

Computer UPS (uninterruptible power supplies) often have the same problem, which can make having a black-out quite an expensive event.

The *Battery LifeSaver* works with 6-24V batteries and can handle currents of up to 20A continuous and 30A peak, making it suitable for use with cordless power tools, emergency lights, small to medium UPS (up to about 300VA) and a wide variety of other devices.

With a quiescent current less than 5µA, it has negligible effect on battery life and as long as the cut-off voltage is set high enough, it won't damage the battery even if left for quite a long time after it has activated (4.3µA continuous discharge equates to less than 38mAh per year).

It's very small – just 46 × 18.5 × 5mm assembled and light too (about 5g) so it can be slipped into a tiny space in a battery compartment. It won't cost a lot to build either, which is good, since if you have use for one, chances are you will have uses for several. We certainly do!

Operation and charging

As shown in Fig.1, the unit connects between the battery and load so that it can stop the load drawing any further power once the battery voltage reaches its cut-off value.

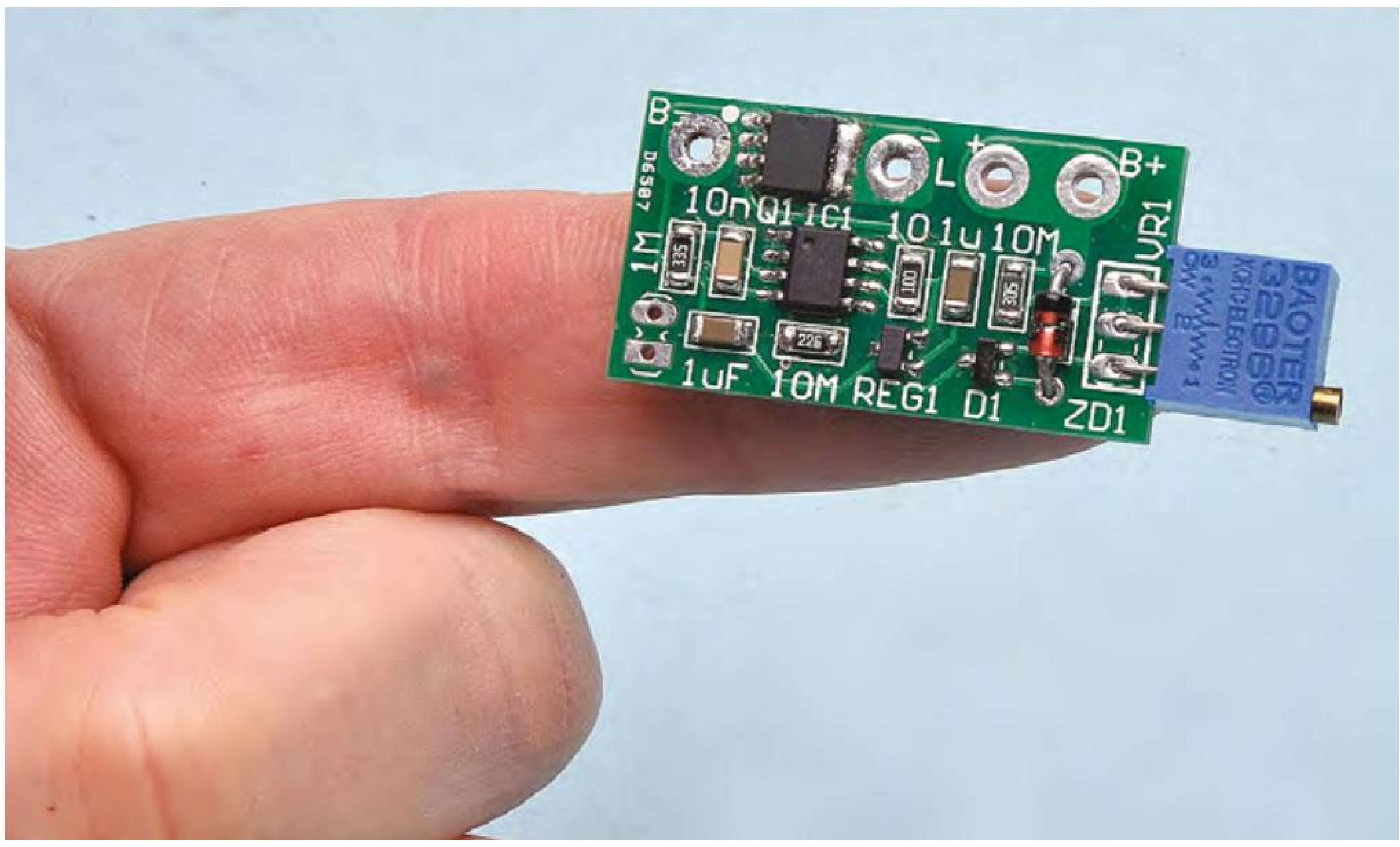
It is based on a MOSFET, shown here as a switch. When the MOSFET is off, the load cannot draw any further power from the battery. The MOSFET's intrinsic diode is reverse-biased in this condition, so no current flows through it either.

The battery can be recharged either by connecting the charger directly across the battery terminals (if they are accessible) or as shown in Fig.1, by connecting the charger across the load terminals, whether or not the load is still connected. Charge current flows in the opposite direction to discharge current, and this path is shown in green.

In many cases, it will be necessary or simply convenient to charge via the load side of the device. In this case, the positive output of the charger is connected directly to the positive terminal of the battery, while the negative output is connected via the internal electronic switch and parallel diode.

If the battery voltage is high enough then the switch is on and so charge current can flow through it and charging proceeds as if the charger was connected across the battery.

With the switch off, current can still flow from the charger to the battery but it must pass through the diode. There will be an associated voltage drop and power loss due to the diode junction, heating up the diode (inside the MOSFET). However, note that because the battery voltage will appear to be near-zero at the load terminals, some chargers may refuse to deliver current in this situation.



Believe it or not, this photo is actually larger than life size, just to show the detail on the tiny (46 × 18.5mm) module. Although it's cheap to build, it could save you a fortune in ruined batteries! Once we attached the input and output leads, we encapsulated it in some transparent heatshrink tube.

If the cut-out has activated, you should limit the charge current to 1.5A or else the diode could overheat. We tested charging under this condition using a Turnigy Accucell 6 charger and it worked fine as long as we turned the charge current down until the battery voltage had come back up a couple of volts. Once the switch is back on (as confirmed by a healthy voltage reading across the load terminals), you can proceed to charge at the full rate.

If your charger is too 'smart' and refuses to supply current with the cut-out activated, it's simply a matter of connecting some sort of current source (or current-limited voltage source) across the load terminals – a plugpack and low-value wire-wound resistor will generally do the trick. It usually doesn't take long to raise the voltage of a flat battery by a volt or two.

Circuit description

The full circuit is shown in Fig.2. We have published similar circuits in the past that used special-purpose ICs, but they can be hard to get, so this one is based on general-purpose parts: a low quiescent current low-dropout linear regulator (REG1), an ultra-low-power comparator (IC1) and a very low on-resistance MOSFET (Q1).

REG1 has a dual purpose. It limits comparator IC1's supply to 5V, which is desirable since IC1 has an absolute maximum rating of 7V. The regulated 5V is also used as a reference for comparison with the battery voltage.

IC1 has rail-to-rail inputs and this means that we can tie its inverting input (pin 2) directly to 5V. In fact, its common-mode input range extends 0.2V beyond both supply rails. Pin 3, the non-inverting input, is connected to a resistive voltage divider that is connected across the battery.

The upper leg of this divider consists of a fixed upper resistor (RU) and a trimpot (VR1) while the bottom leg is a single resistor (RL). RU and RL are chosen so that VR1 can be adjusted to give 5V on pin 3 of IC1 when the battery voltage is at its lower operating limit.

With the battery voltage above this limit, the voltage at pin 3 of IC1 is above that of pin 2 and so the comparator output (pin 6) is high, switching

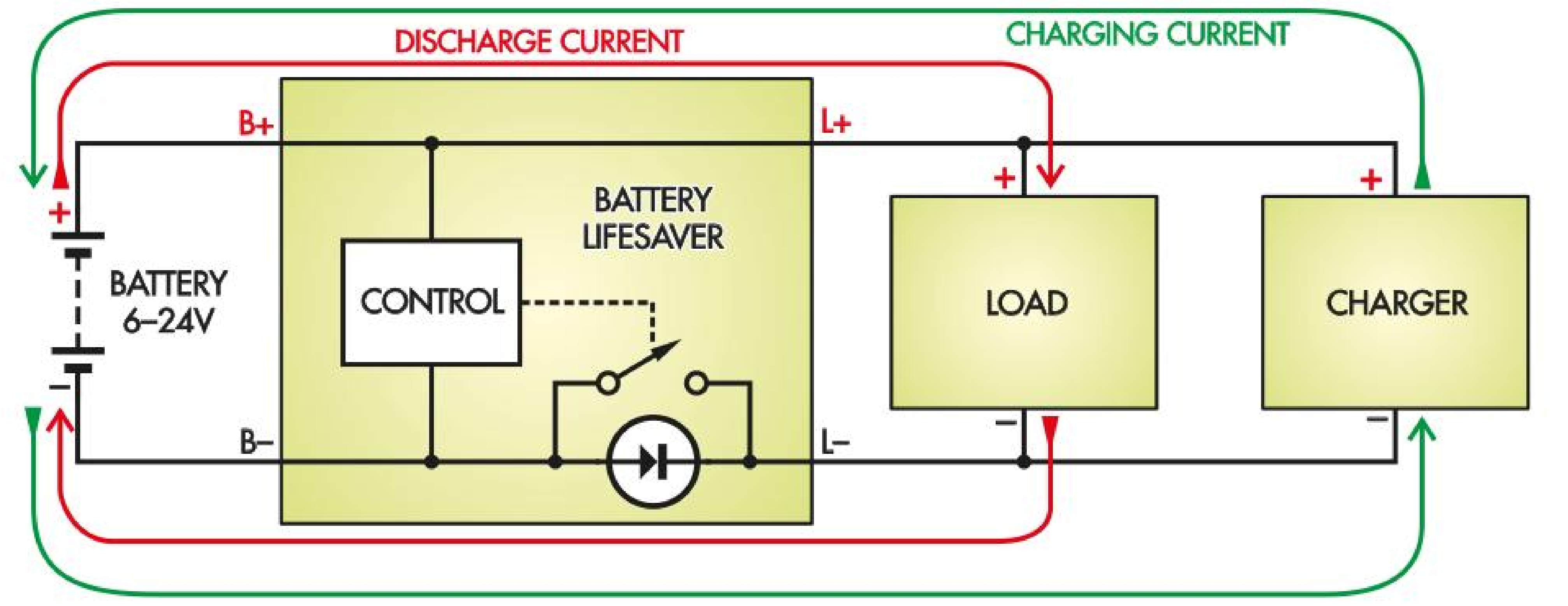
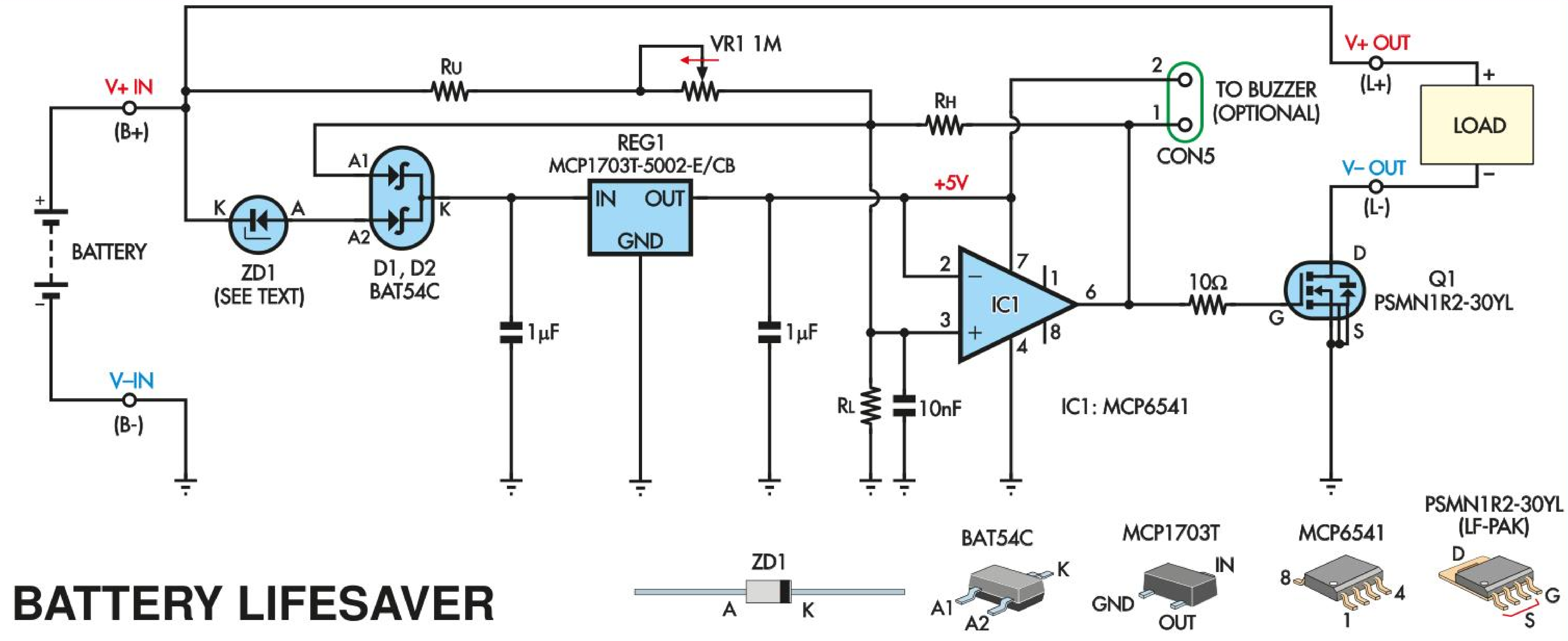


Fig.1: block diagram for the *Battery Lifesaver*. The unit is connected between the battery and load and disconnects the two (at the negative end) if the battery voltage drops below a threshold. The battery can still be charged in this case, at a limited current, until the voltage rises enough for the cut-out to deactivate, at which point full charge current can resume.



BATTERY LIFESAVER

Fig.2: circuit diagram for the *Battery LifeSaver*. It's based on a low-dropout 5V regulator (REG1), very low power comparator (IC1) and MOSFET Q1, which acts as the switch. Values for resistors RU, RH and RL are chosen to suit a particular battery cut-out voltage threshold; VR1 provides fine adjustment of this voltage. ZD1 is selected to keep the supply voltage to REG1 within its ratings.

on MOSFET Q1 via a 10Ω resistor. This connects the load to the battery. When on, Q1 not only has a very low on-resistance (about 1.3mΩ) but is fully on with its gate just 4.5V above its source.

If the battery voltage drops too much, the voltage at pin 3 of IC1 goes below that at pin 2, the comparator output goes low and MOSFET Q1 turns off. The only remaining load on the battery is the circuit itself, drawing about 3.2-4.5µA.

Resistor RH, connected between the output and non-inverting input of IC1, gives a small amount of positive feedback, which provides 1-2V of hysteresis for the circuit. Its value is selected so that this hysteresis is about 8% of the battery voltage. Without this, as soon as the load is switched off, the battery voltage would rebound and this will cause the load to be switched back on and the circuit would oscillate.

Say the low voltage cut-out threshold is set to 19.8V (for a 24V Li-Po battery). Once the output of IC1 goes high, the switch-on voltage rises to about 21.4V. The battery is unlikely to rebound this much – at least, not right away – so the MOSFET will remain off until the battery is re-charged. This hysteresis should be sufficient for most batteries, but if necessary, it can be increased by lowering the value of RH.

The 10nF capacitor across RL filters out noise which may be picked up due to the high impedance of the divider network and smooths battery voltage ripple. It also slows the action of this hysteresis considerably, but IC1 has a small amount of built-in hysteresis (about 3.3mV worth) which helps compensate for this.

REG1 has 1µF ceramic input bypass and output filter capacitors for stability, the minimum suggested value for this part. Dual Schottky diode D1/D2 protects the circuit against reverse battery polarity, although it won't stop current flowing through Q1's body diode and the load, if connected. .

Zener diode ZD1 reduces the battery voltage for REG1 and its voltage is selected to suit the type of battery used. REG1's absolute maximum input is 16V. For batteries well below 16V, ZD1 is replaced with a link (see Table 1).

During operation, REG1 consumes about 2µA, while IC1 draws just 600nA. The rest of the quiescent current flows through the resistive divider, hence the resistors used have as high a value as is practical to minimise this current. This is why we have used a combination

When we say tiny, we mean it: here is the *LifeSaver* sitting on top of a 12V, 7Ah SLA battery – it's not even as high as the spade lugs!

of resistors and a trimpot to set the cut-off voltage; the highest value of trimpot commonly available is 1MΩ.

Optional buzzer/LED

The PCB has a pair of pads so that a piezo buzzer or LED can be connected to indicate when the battery voltage drops below the cut-off threshold. However, fitting this may be not a good idea if you are concerned about the extra current drain on a battery which has been drained to the cut-off voltage.

A buzzer/LED could run the battery flat in a matter of hours, so you will need to immediately recharge it once it sounds/lights up.

If you do want to fit a buzzer or LED, it will be driven at 5V by the output of comparator IC1, which can sink a maximum of 30mA. LEDs will require a series current-limiting resistor.

Component selection

Since the battery voltage divider is formed from a combination of fixed resistors and trimpot VR1, we must change the values of these resistors so that the adjustment range of VR1 includes the desired cut-off voltage for your battery.

High value input dividers for comparators pose a problem in that the hysteresis resistor typically must be a much higher value, so we are limited by the highest value readily available. Luckily, it's quite easy to get resistors up to about 22MΩ in SMD packages, which is higher than the typical maximum of 10MΩ for through-hole parts.

To determine which parts you need, first locate your battery or its closest equivalent in Table 1 and read off the value for ZD1. Next, decide which cut-off voltage you want to use; in very high current drain applications (10A+), especially when using a relatively small battery, you may want to set it a bit lower than specified.

Once you have determined the cut-off voltage to use, find an entry in Table 2, which has a range covering it, and then read off the values for resistors RL, RU and RH. These are chosen to give a hysteresis of about 8% of the battery voltage, thus the hysteresis is

Parts List – Battery LifeSaver

1 double-sided PCB, available from the *EPE PCB Service* coded 11108131, 34 × 18.5mm
1 50mm length 25mm-diameter heatshrink tubing
1 length heavy-duty black wire (to suit installation)
1 length heavy-duty red wire (to suit installation)
2 female 6.4mm spade quick connectors (optional; for use with gel cell batteries)
2 male 6.4mm spade quick connectors (optional; for use with gel cell batteries)

Semiconductors

1 MCP6541-E/SN ultra-low-power comparator (IC1) (RS Components 669-6200)
1 MCP1703-5002-E/CB micropower LDO 5V regulator (REG1) (element14 1439519)
1 PSMN1R2-30YL 30V 100A MOSFET (Q1) [SOT-669/LFPAK] (element14 1895403)
1 BAT54C dual Schottky diode (D1) [SOT-23] (element14 1467518)
1 0.4W or 1W Zener diode (see Table 1 for voltage) (ZD1)

Capacitors (all SMD 3216/1206)

2 1µF 50V (element14 1857302)
1 10nF 50V (element14 8820155 or similar)

Resistors (SMD 3216/1206)

1 10Ω
plus three resistors, 330kΩ-22MΩ, as per Table 2
1 1MΩ 25-turn vertical trimpot (VR1)

Visit Jaycar Electronics UK (www.jaycar.co.uk) for a Battery LifeSaver kit: Cat No KC-5523 @ £11.00

ST Micro's LFPAK series SMD MOSFETs

MOSFET Q1 is an ST Micro part with an incredibly low on-resistance – barely more than a milliohm. It is rated to carry 100A but it will dissipate around 1W at 30A (I^2 x R) so without heatsinking (other than the PCB), it won't handle much more than that.

Its on-resistance is so low that losses in the MOSFET itself are a minor component of the dissipation, most of it being in the PCB and wiring. This is only really possible with SMDs since a TO-220 through-hole package has 1mΩ of resistance in the package/leads alone.

By comparison, the LFPAK package (also known as SOT-669) has a resistance of just 0.2mΩ. The semiconductor die is sandwiched between the metal drain pad on the bottom of the device (which also acts as a heat spreader) and a metal plate on top, which also forms the three source leads (pins 1-3). This gives a very large contact area between the device leads and the MOSFET itself, hence the low resistance possible.

The LFPAK has roughly the same footprint as an 8-pin Small Outline Integrated Circuit (SOIC-8), a common SMD IC package. There is a lot of equipment already designed to handle SOIC parts – pick and place machines, storage schemes, etc – and these can generally work with LFPAK MOSFETs with little or no modification.

At a pinch, SOIC-8 MOSFETs can be substituted for LFPAK devices and can be soldered to the PCB without needing to modify it. However, losses will be higher in this case. MOSFETs in LFPAK use the same pin configuration as typical N-channel MOSFETs in SOIC packages. For more information, see: **www.nxp.com/documents/leaflet/75016838.pdf**

Table 1: battery types, voltages and values for ZD1

Battery type	Nominal	Fully charged	Cut-out (best life)	(Safe)	(Minimum)	ZD1
Lead-acid	6V	7.2V/7.35V*	5.75V	5.5V	5.25V	link
Lead-acid	12V	14.4V/14.7V*	11.5V	11.0V	10.5V	3.3V
Lead-acid	24V	28.8V/29.4V*	23.0V	22.0V	21.0V	15V
LiFe 2S	6.6V	7.2V	6.2V	6.0V	5.6V	link
Li-ion 2S	7.2V	8.2-8.4V	6.6V	6.0V	5.4V	link
Li-po 2S	7.4V	8.4V	7.2V	6.6V	6.0V	link
LiFe 3S	9.9V	10.8V	9.3V	9.0V	8.4V	link
Li-ion 3S	10.8V	12.3-12.6V	9.9V	9.0V	8.1V	3.3V
Li-po 3S	11.1V	12.6V	10.8V	9.9V	9.0V	3.3V
LiFe 4S	13.2V	14.4V	12.4V	12.0V	11.2V	3.3V
Li-ion 4S	14.4V	16.4-16.8V	13.2V	12.0V	10.8V	3.3V
Li-po 4S	14.8V	16.8V	14.4V	13.2V	12.0V	5.1V
LiFe 5S	16.5V	18.0V	15.5V	15.0V	14.0V	5.1V
Li-ion 5S	18.0V	20.5-21.0V	16.5V	15.0V	13.5V	8.2V
Li-po 5S	18.5V	21.0V	18.0V	16.5V	15.0V	8.2V
LiFe 6S	19.8V	21.6V	18.6V	18.0V	16.8V	8.2V
Li-ion 6S	21.6V	24.6-25.2V	19.8V	18.0V	16.2V	8.2V
Li-po 6S	22.2V	25.2V	21.6V	19.8V	18.0V	10V

Note: 2S/3S/4S/5S/6S refers to the number of cells in series   * gel cell or AGM type lead-acid battery

roughly proportional to the number of cells for a given battery chemistry.

As mentioned earlier, you can adjust the value for RH if necessary – lower values give more hysteresis and higher values less. This will not affect the cut-off voltage, although hysteresis does vary slightly as VR1 is adjusted.

Construction

The *Battery LifeSaver* is built on a PCB which is available from the *EPE PCB Service,* coded 11108131, measuring 34 × 18.5mm. Referring to the overlay diagram (Fig.3), start by soldering MOSFET Q1. It has a large pad on the underside which must be in intimate contact with the large pad on the PCB to ensure both low resistance (so it can handle high currents) and a good thermal bond for proper heat dissipation.

To achieve this, first spread a moderately thin layer of solder paste evenly over the pad and a good dollop of it on the smaller pin 4 pad, at lower left. Position Q1 over its pads and press it down, then apply heat to the small pin 4 pad so as to melt the solder paste until Q1 is held in place. You may find you have to add some solder wire to get a solid joint.

Check that Q1 can't move, then examine its alignment. In particular, ensure that the other three pins are correctly positioned over their pads and the tab is not totally covering the pad to which it is to be soldered; there should be a thin sliver of pad visible – although this may be obscured by solder paste.

To adjust the alignment, re-heat the solder on pin 4.

Once you are happy with its position, melt the solder paste along the edge of the large tab by running the tip of the iron along up and down along the exposed section. It may help to add a bit more solder.

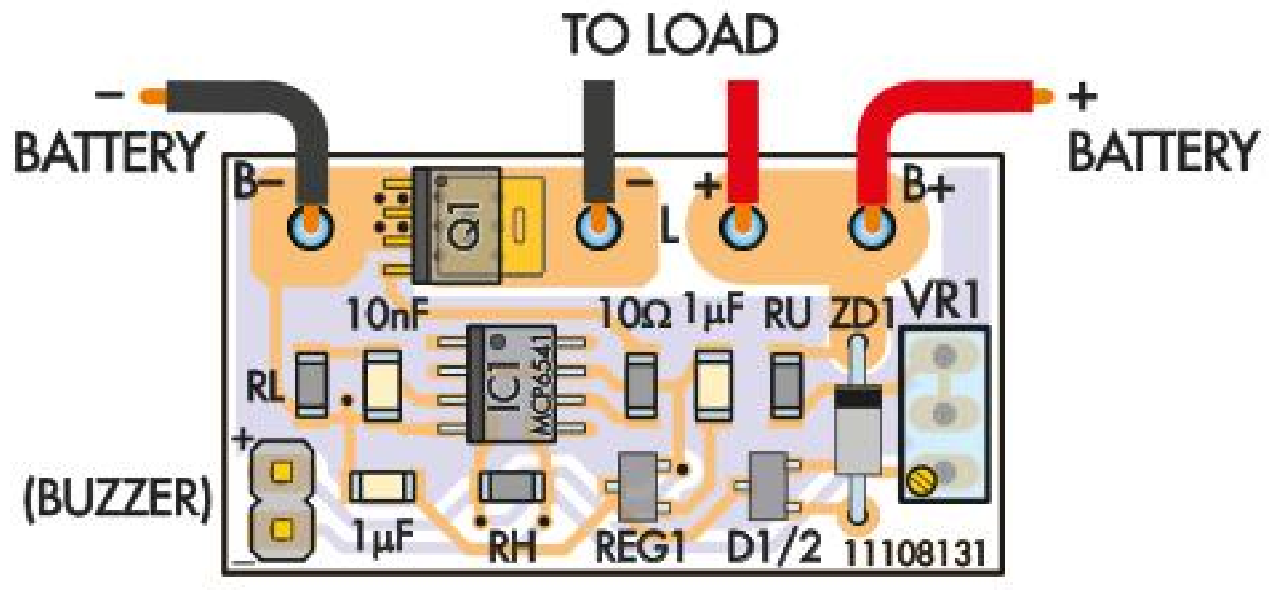


Fig.3: follow this PCB overlay diagram to build the unit. Most parts are SMDs and all mount on the top side of the board. VR1 can be laid over to keep the whole thing relatively thin, so it can be squeezed next to a battery. Heavy-duty wires to the battery and load solder directly to the large pads at top. Use of the pads at lower-left is optional, for connecting a piezo buzzer for a low-voltage alarm.

You will need to keep the tab heated for several more seconds so that the paste underneath all melts and fills the gaps, forming a solid junction.

Note that this will require a fairly hot iron as there is a large area of copper connected to this pad. Note also that you will need to put the PCB on a heat-resistance surface as the underside will get very hot indeed.

To avoid overheating the MOSFET itself, stop after about ten seconds. You may need to let it partially cool down and then apply heat for another ten seconds or so, to ensure all the solder paste has melted.

When this happens, the volume of flux smoke produced should drop right off. You can then solder the remaining pins one at a time and clean up any bridges between them using solder wick. If necessary, clean up using isopropyl alcohol.

IC1 is a snack by comparison; it is the same size and has the same pin spacing, but there is no big pad underneath, so you simply pin it down by one lead, check the alignment and then solder the remaining pins once it is correctly oriented.

For the rest of the SMD components, apply some solder to one of the pads, heat it, slide the part in place using angled tweezers, remove the heat and check the alignment. If it's OK, make the remaining solder joint(s) and then refresh the first one with a dab of extra solder.

Don't get REG1 and D1 mixed up because they look very similar; the resistors will be labelled with their value (although you may need a magnifying glass to read it) but the capacitors won't be.

If you do get confused, you should be able to tell which is the 10nF as it will be thinner than the other two.

With the SMD components in place, fit ZD1 with the orientation shown and then VR1, with its adjustment screw towards the bottom of the board. You can bend its leads over before soldering, as we have, to keep the overall assembly thin so that it will fit into tight spaces.

Note that if you are going to use the unit with a sealed lead-acid battery ('gel cell'), these are often fitted with spade lugs.

So you could solder wires to the PCB and crimp female spade lugs onto those connected to the B+/B– terminals and male spade lugs to those connected to the L+/L– terminals. That would then allow you to easily connect the device in-line between the battery and device without any additional soldering.

Testing and adjustment

The easiest way to set up the *Battery LifeSaver* is using a variable voltage power supply (eg, a bench supply) but if you don't have one, you can instead connect a fully charged battery (or power supply with a similar voltage) across a 1-10kΩ potentiometer.

The pot wiper connects to the B+ terminal on the PCB, while the negative terminal of the power supply goes to B–.

We used small hook probes to make the connection to these terminals, to avoid having to solder them initially (see photo) but if you do solder wires on, it's probably a good idea to keep them long and use thick, heavy-duty wire so that you can also use them for the final wiring.

Adjust the bench supply or pot to give the board close to the nominal battery voltage (measured across B+ and B–), then measure the current flow by connecting a multimeter, set to mA or µA, in series with one of the board's supply leads.

You should get a reading of around 5µA. If it's more than 10µA or less than 2µA then something is wrong and you will need to carefully check the assembly (note that not all multimeters can read such low currents with precision).

Set the DMM to volts mode and measure between the + terminal of CON5 (upper) and the B– battery terminal. Assuming your DMM is accurately calibrated, you should get a reading in the range of 4.95-5.05V.

Now adjust VR1 fully anti-clockwise (until it clicks) and measure the resistance between the L– and B– terminals. The reading should be close to 0Ω, meaning Q1 is on. If not, check the supply voltage and try turning it up slightly, but don't exceed the full-charge voltage of your battery.

Assuming Q1 is on, reduce the supply voltage to the PCB until it is at your desired battery cut-off voltage, as measuring between B+ and B–.

Confirm that Q1 is still switched on, then slowly turn VR1 clockwise until Q1 switches off and the resistance reading increases dramatically. It should be above 10MΩ and may give a reading of 'oL' (ie, effectively open circuit) on your DMM.

To check this, we simply clipped the test leads connected to L– and B– onto our DMM probe tips and used clip leads to connect the power supply to B+ and B–. This allowed us to vary the voltage while watching the MOSFET's resistance.

You can confirm that the board is working properly by turning the supply voltage up by the hysteresis voltage (a couple of volts should do); Q1 should then turn back on again.

Installation

Once you have soldered the leads to the PCB, it's a good idea to sleeve the whole thing with 25mm diameter heatshrink tubing so that once it's inside the battery compartment, or secured to the outside of a battery, it can't short against battery terminals or any other exposed metal.

Wire it up according to Fig.3. There are two different ways to connect the load's positive terminal. Ideally, it should go straight to the battery's positive terminal, but since that will already be wired to the *Battery LifeSaver* board, it may be easier to connect it to the L+ terminal on the PCB instead.

This means the full-load current has to pass through the PCB twice, which will slightly increase losses but should not cause any problems within the ratings we have provided.

Table 2: resistor values for different cut-out voltage ranges

Cut-out range	Hysteresis	RL (1%)	RU (1%)	RH	Iq*
5.2-5.6V	~0.3V	10MΩ	330kΩ	10MΩ	3.2µA
5.6-5.9V	~0.4V	10MΩ	1.0MΩ	15MΩ	3.2µA
5.8-6.4V	~0.5V	6.8MΩ	1.0MΩ	15MΩ	3.7µA
6.4-7.4V	~0.5V	3.9MΩ	1.0MΩ	15MΩ	4.4µA
7.4-8.7V	~0.6V	3.3MΩ	1.5MΩ	15MΩ	3.5µA
8.4-9.7V	~0.6V	3.3MΩ	2.2MΩ	22MΩ	3.8µA
9.6-11.0V	~0.8V	3.3MΩ	3.0MΩ	22MΩ	4.4µA
11.0-12.3V	~1.0V	3.3MΩ	3.9MΩ	22MΩ	4.3µA
12.2-13.6V	~1.1V	3.3MΩ	4.7MΩ	22MΩ	4.3µA
13.6-15.1V	~1.2V	3.0MΩ	5.1MΩ	22MΩ	4.6µA
15.5-17.1V	~1.4V	2.7MΩ	5.6MΩ	22MΩ	4.7µA
16.2-17.9V	~1.6V	3.0MΩ	6.8MΩ	22MΩ	4.6µA
17.7-19.3V	~1.6V	2.7MΩ	6.8MΩ	22MΩ	4.5µA
19.3-21.1V	~1.6V	2.4MΩ	6.8MΩ	22MΩ	4.6µA
20.6-22.6V	~1.6V	2.2MΩ	6.8MΩ	22MΩ	4.9µA
22.2-24.2V	~1.8V	2.2MΩ	7.5MΩ	22MΩ	4.9µA
23.7-25.8V	~2.0V	2.2MΩ	8.2MΩ	22MΩ	4.9µA

* Approximate quiescent current at cut-off voltage

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Stop those intrusive meal-time phone calls!

By JOHN CLARKE

Tone
Pause
Store
Clear
Recall Flash
Redial
Touchfone
Telecom Touchfone 200R
Minutes
15
30
60
90
120
END
SET/START
TIMER
DO NOT DISTURB
PHONE TIMER

"DO NOT DISTURB!" Phone Timer

Do marketing companies conspire to call you right on dinner time? It certainly seems so! Or perhaps you want the phone to be out of action for an hour or so, while you take an afternoon nap? This little timer will solve both those problems and it will 'remember' to put the phone back in action because we know how easy it is to forget!

You know how it goes – you sit down to dinner and you are savouring your first mouthful... and then the &(*%$ ^ phone rings.

It might be some nincompoop from a marketing company selling you something that you cannot possibly do without, or a call centre from who knows where! Or it could even be one of your closest friends or relatives. Whoever it is, it doesn't matter – you don't want to talk – you just want to enjoy your meal.

Of course, you could simply take the phone handset out of the cradle ('off-hook' in 1950s telephone speak) and that effectively silences it... but then you realise a few days later that the phone has been awfully quiet. Doh!

Features

- Five convenient time settings from 15 to 120 minutes
- Time set indication
- Time remaining indication
- Automatically returns phone to ‘ready’ (on hook) after time-out
- Easy push-button timer setting
- End button

And yes, many cordless phones have a ‘do not disturb’ button, but the same problem applies; you forget to switch it back to normal operation.

Worse still, if you do want to have a nap, pushing the ‘do not disturb’ button does not usually silence the phone completely; it will ring several times before it goes to message mode – which can be pretty frustrating if you are just drifting off to the land of Nod.

That’s where our new *‘DO NOT DISTURB!’ Phone Timer* is such a good solution.

It connects in parallel with your phone, or one of your phone extensions if you have more than one (or with your cordless phone base station, if you don’t have conventional phones).

Then, if you want to disable the phone you just press the Set/Start button a few times to set the time period you want and the phone will be muted. Callers will get the engaged signal – so they won’t have to pay for a call.

You get peace and quiet for a preset 15, 30, 60, 90 or 120 minutes.

After the preset time has passed, the *Timer* will reconnect the phone.

If you finish your meal or nap or whatever earlier than you anticipated, (or maybe son/daughter/spouse/etc says they’re expecting an absolutely vital call!) just press the End button to restore phone operation. Simple.

LEDs show the time

Three LEDs display the set time. With one LED on, they indicate 15, 60 or 120 minutes. Intermediate set times are indicated with two LEDs on, ie, 30 or 90 minutes.

When you push the Set/Start button the LEDs will show the previous set timer period. Further button pushes will cycle though the available times: 90, 120, 15, 30 and so on. Just pick the one you want.

Timer operation starts as soon as the period is selected. After five seconds, the LED (or LEDs) will flash at a one-second rate and they also indicate the next highest time-out period remaining. All LEDs extinguish at the end of the time-out period when normal phone operation is restored.

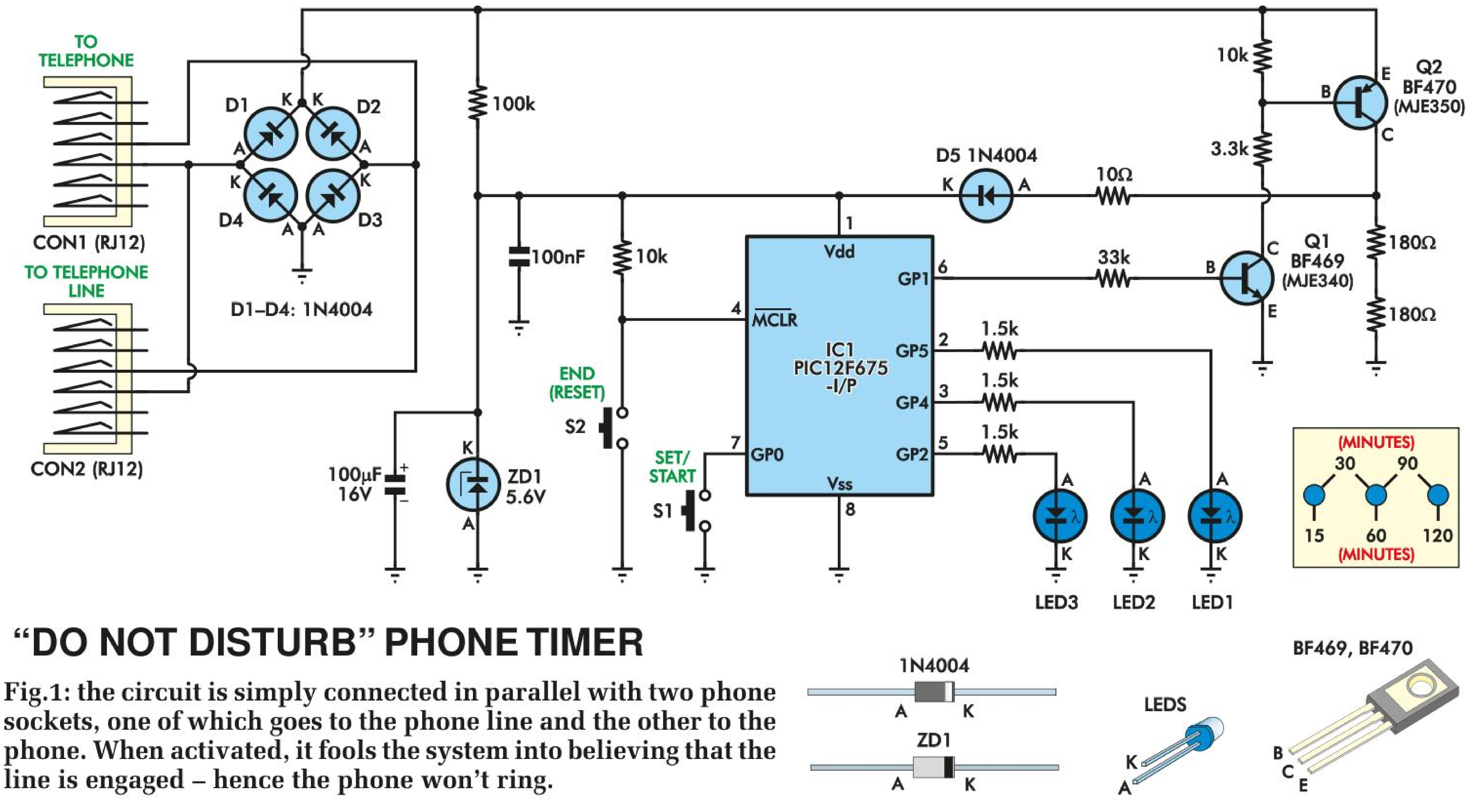
What happens if you lift a phone handset off the cradle while the unit is timing? That’s a bit uncertain – it depends on your particular phone and how it reduces the DC voltage across the phone lines from a nominal 50V DC to around 6V or thereabouts. Either way, neither the phone nor the timer can be damaged.

The *DO NOT DISTURB! Phone Timer* is housed in a small plastic box with the telephone line plugged into one RJ12 socket and the telephone into the second RJ12 socket, so you’ll need a short phone ‘extension’ cable .

Both the RJ12 sockets are located at one end of the box. On the top of the box are the two pushbuttons (Set/Start and End) and the timer indication LEDs. No batteries are required because the circuit is powered from the phone line.

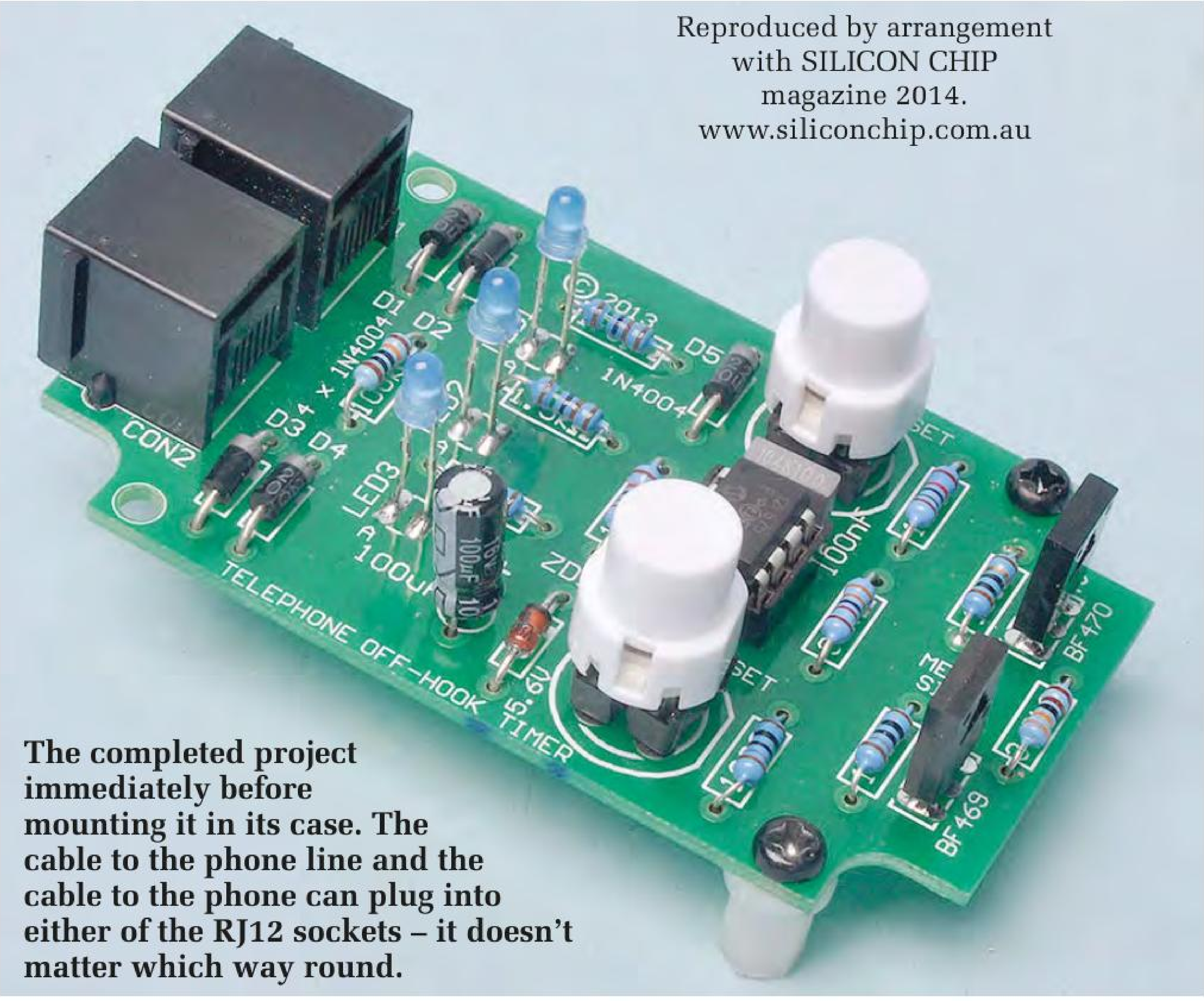
Is it legal?

Strictly speaking, you aren’t allowed to connect any non-approved device to the phone line, in case it causes damage to the line/exchange and/or



“DO NOT DISTURB” PHONE TIMER

Fig.1: the circuit is simply connected in parallel with two phone sockets, one of which goes to the phone line and the other to the phone. When activated, it fools the system into believing that the line is engaged – hence the phone won’t ring.



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The completed project immediately before mounting it in its case. The cable to the phone line and the cable to the phone can plug into either of the RJ12 sockets – it doesn't matter which way round.

endangers those working on the telephone system.

However, this device is powered by the phone line itself, so no dangerous voltages can possibly get back into the system.

Circuit details

Fig.1 shows the circuit, which comprises an 8-pin microcontroller, a couple of high voltage transistors, three LEDs, some diodes and capacitors. The microcontroller provides the timing, switches the high voltage transistors and drives the LEDs.

There are two RJ12 connectors, CON1 and CON2, which provide connection to the incoming phone line and to one of the phones in the dwelling. These connectors are wired in parallel, so there is no break in the telephone line connection.

When the phone is not in use, (ie, 'on-hook') there is about 50V DC present across the line. The bridge rectifier, consisting of diodes D1-D4, feeds that 50V DC to the rest of the circuit and ensures correct polarity.

The microcontroller, IC1, is powered from 5.6V DC, derived from a 100kΩ resistor, Zener diode ZD1 and 100µF capacitor. Thus, the 50V from the telephone line provides about 400µA to ZD1, while IC1 draws about 100µA.

This current is low because IC1 is initially set in sleep mode where it is stopped from running, with its internal oscillator off. IC1 also has a brownout detector incorporated so that the slow start up voltage applied through the 100kΩ resistor and 100µF supply capacitor allows the IC to reset correctly.

Current draw is higher when the timer function is started with Set/Start switch S1. This current can be up to 10mA and the 100kΩ resistor across the telephone supply will not provide this.

We derive the extra supply current in another way. When the set switch is pressed, the GP1 output of IC1 goes high (to 5.6V) and this switches on transistor Q1 via its 33kΩ base resistor. Q1 in turn switches on transistor Q2 and this connects two series-connected 180Ω resistors across the telephone supply. The load drops the telephone line to around 6V and it becomes 'off-hook'.

With transistor Q2 on, supply for IC1 is fed from the 6V telephone supply via a 10Ω resistor and diode D5. This provides the required extra current.

Q1 and Q2 are high voltage transistors, specified to cope with the high AC of around 140V peak-to-peak when the telephone rings.

Note, if the handset (receiver) is lifted off the telephone, the *DND Timer* might reset. That's because of the extra load on the telephone line. If you still want the *DND Timer* to work, you should hang up the phone and push the Set/Start button, which will restart the timing cycle.

LED1 to LED3 are driven by their respective micro outputs at GP5, GP4 and GP2, each via 1.5kΩ resistors.

Normally, the GP0 input is pulled to the 5.6V supply via an internal pull-up resistor. This input drops to 0V when the set switch is pressed, waking up IC1 and starting the internal program running. IC1 goes back to sleep at the end of the time-out period. Both Q1 and Q2 are then switched off and normal phone operation is resumed.

IC1 can also be reset by pressing switch S2. This pulls the $\overline{\text{MCLR}}$ (Master Clear) low to reset the IC. Once released, the 10kΩ resistor to V_{DD} pulls the $\overline{\text{MCLR}}$ high and the IC goes back to sleep with the internal oscillator stopped.

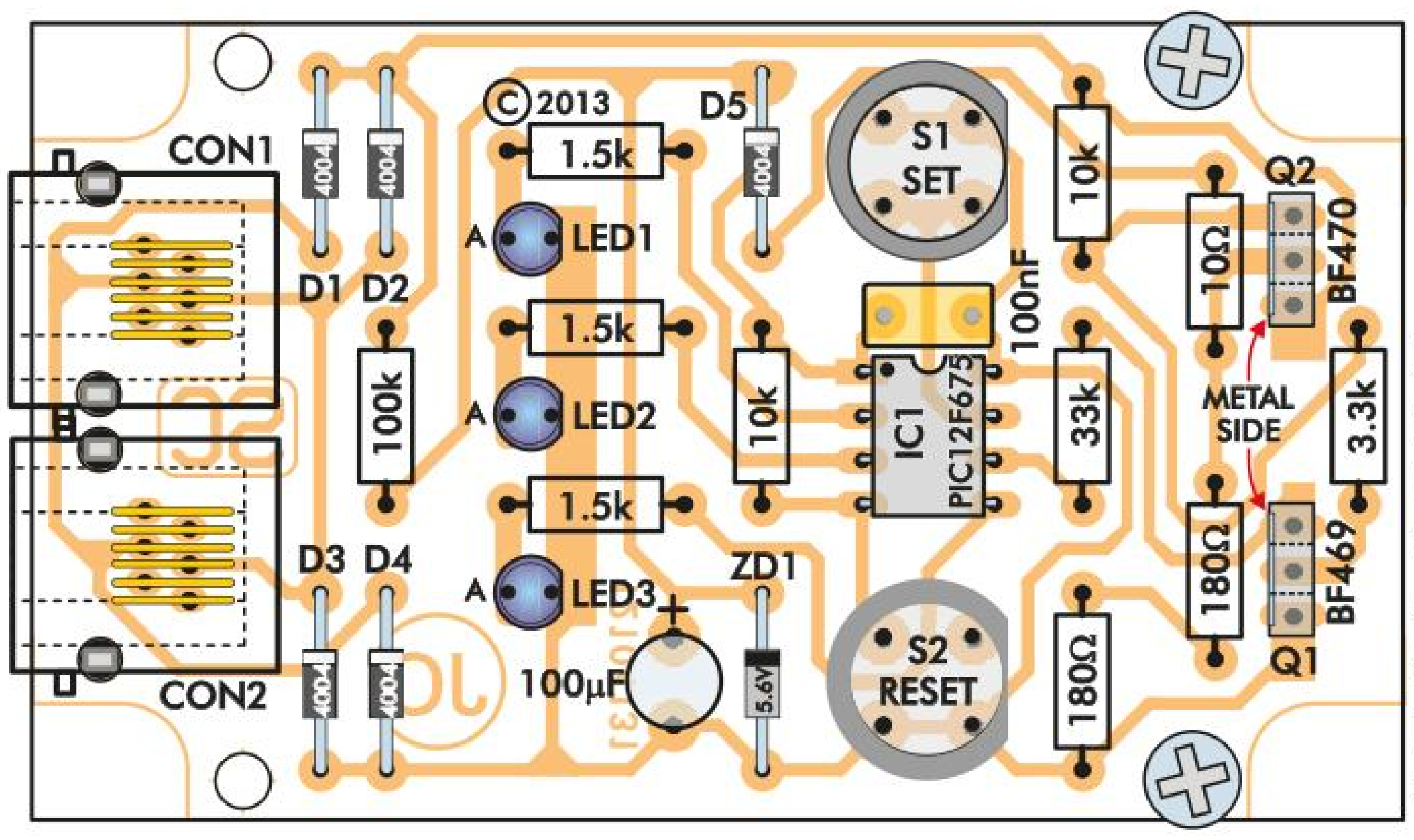
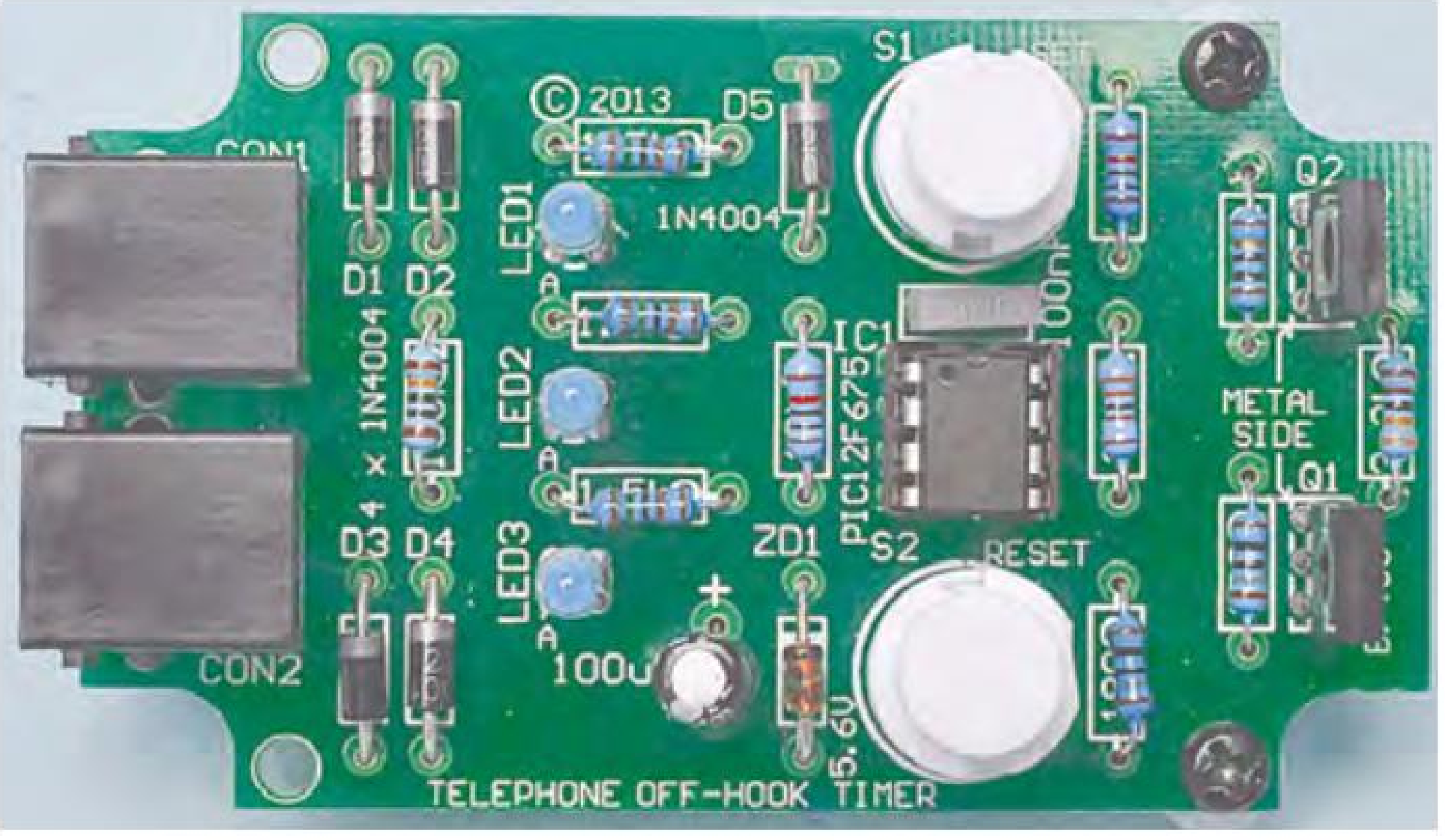


Fig.2 (left): component overlay with matching same-size photo at right.



Construction

The *DND Timer* is constructed using a PCB which is available from the *EPE PCB Service*, coded 12104131, measuring 79 × 46mm. It is housed in a small plastic box 83 × 54 × 31mm, used 'upside down' – ie, the normal lid becomes the base and the four rubber 'pips' which hide the case screws act as feet.

We used a translucent blue box (because it looks cool!) but black or grey boxes of the same size are also suitable. A label measuring 48 × 78mm affixes to the lid of the box. If you use the blue box this label can go inside the lid and is thus protected against damage.

At one end of the box are located the two RJ12 PCB mount sockets. Fig.3 shows the details.

Before installing the parts, check the PCB for any faults. If you are using a board supplied from *EPE* or building from a kit, you will find that these PCBs are of excellent quality and rarely have any faults. If you do happen to find a fault (open track, hole not drilled etc) repair it before assembly.

Follow Fig.2 when installing the components. Install the resistors, diodes and the Zener diode first. The resistors are colour coded and the table shows the colour bands for each resistor used.

A digital multimeter should also be used to check the values of resistance because it's easy to mistake red for orange or brown, especially on tiny resistors.

Make sure the diodes and Zener diode are installed with the correct polarity – the striped end must be oriented as shown in the overlay diagram.

We use two types of IC sockets. One is the DIP8 socket for IC1, which must be oriented with the notched end as shown on the overlay diagram. Do not insert the IC into the socket yet.

The other sockets are DIP6 types used to raise switches S1 and S2 sufficiently above the PCB to protrude through the box lid. These sockets will need to be cut (using wire cutters) into two separate 3-way single in-line sockets and with the centre two socket pins removed before installing on the PCB. The switches must be inserted into these sockets positioned with the 'flat' on the switch oriented as shown on the overlay diagram.

Capacitors can be installed next. The electrolytics are polarised – install them with the polarity shown. Likewise, transistors Q1 and Q2 must be mounted in the right positions and they must be oriented correctly – their metal sides face away from the PCB edge. Solder these in so that the top of the transistor body is 15mm above the top of the PCB.

LEDs need to poke through the top panel, so are mounted with the top of each lens 17mm above the PCB surface. Make sure the LEDs are oriented correctly with the anode (longer lead) positioned in the pad marked 'A'.

We used blue LEDs, but you can use aqua, red, green, yellow, orange or white; whatever is your favourite. (You don't even need to use the same colours, but you might end up with different brightness LEDs).

Testing

To test the *DO NOT DISTURB! Phone Timer*, first make sure that IC1 is still out of its socket and then plug the telephone line into one of the RJ12 sockets (you don't need the phone itself plugged in yet).

Measure the voltage across Zener diode ZD1. This should be around 5 to

Parts List – DO NOT DISTURB! Timer

1 PCB available from the *EPE PCB Service* code 12104131, 79 × 46mm
1 panel label 48 × 78mm
2 UB5 plastic box, 83 × 54 × 31mm
2 RJ12 PCB mount sockets (CON1,CON2)
2 SPST PCB mount snap action round white switches (S1,S2)
1 DIL8 IC socket
2 DIL6 standard wiper contact IC sockets
2 10mm M3 tapped spacers (or use 9mm spacers with washers to make up the extra 1mm)
2 M3 × 6mm screws
1 300mm RJ12 6P/4C extension cable

Semiconductors

1 PIC12F675-I/P microcontroller programmed with 1210413A (IC1)
1 BF469/MJE340 NPN transistor (Q1)
1 BF470/MJE350 PNP transistor (Q2)
3 3mm high brightness LEDs (LED1-LED3)
5 1N4004 400V diodes (D1-D5)
1 5.6V 1W Zener (1N4734) (ZD1)

Capacitors

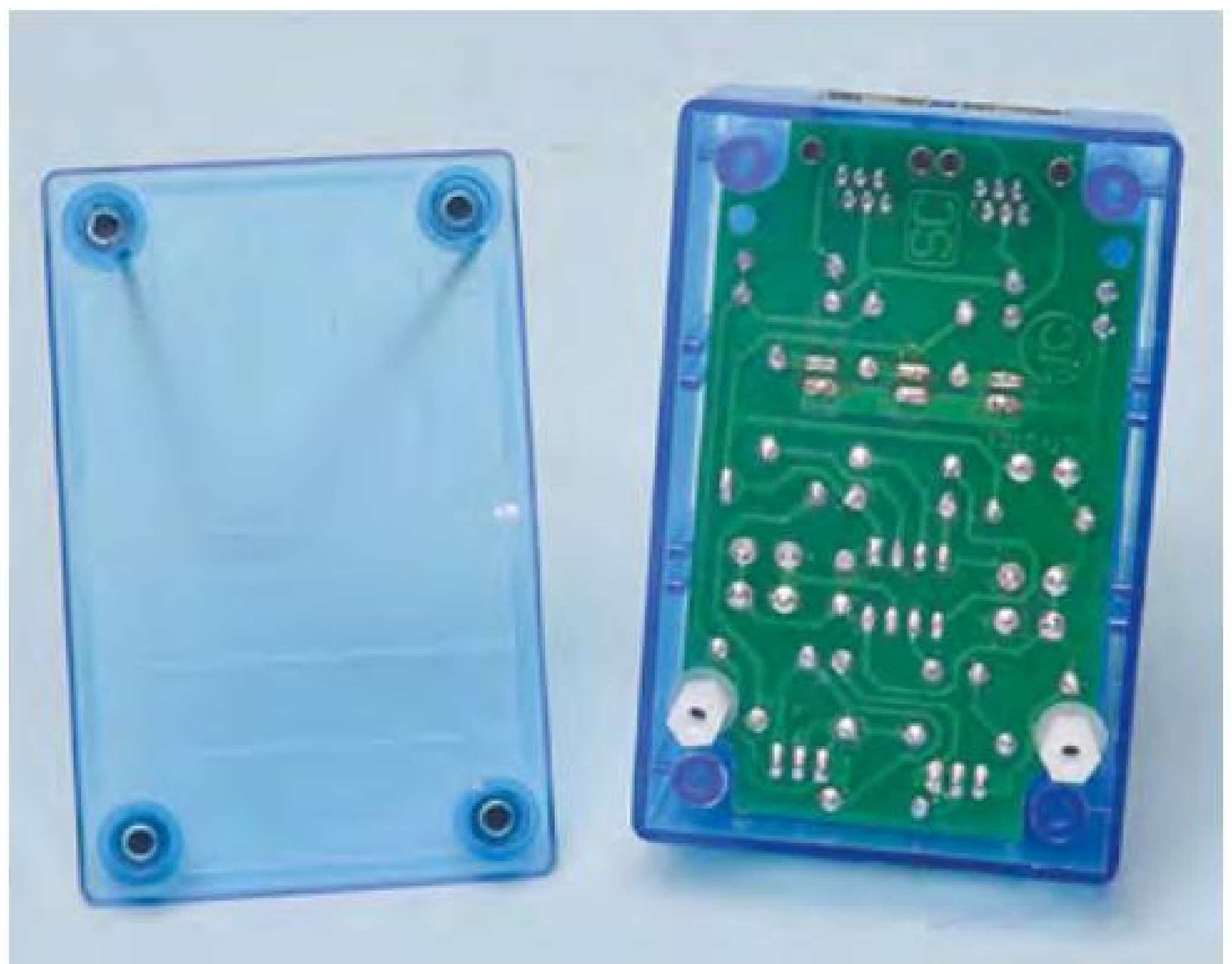
1 100µF 16V PC electrolytic
1 100nF MKT polyester

Resistors (0.25W 1%)

1 100kΩ 1 33kΩ 2 10kΩ 1 3.3kΩ
3 1.5kΩ 2 180Ω 1 10Ω

Cable

Note: you will need an RJ12 to 'BT' cable, available on eBay.co.uk



The case is used upside down, with the lid as the base. Here the PCB is shown fitted into the case.

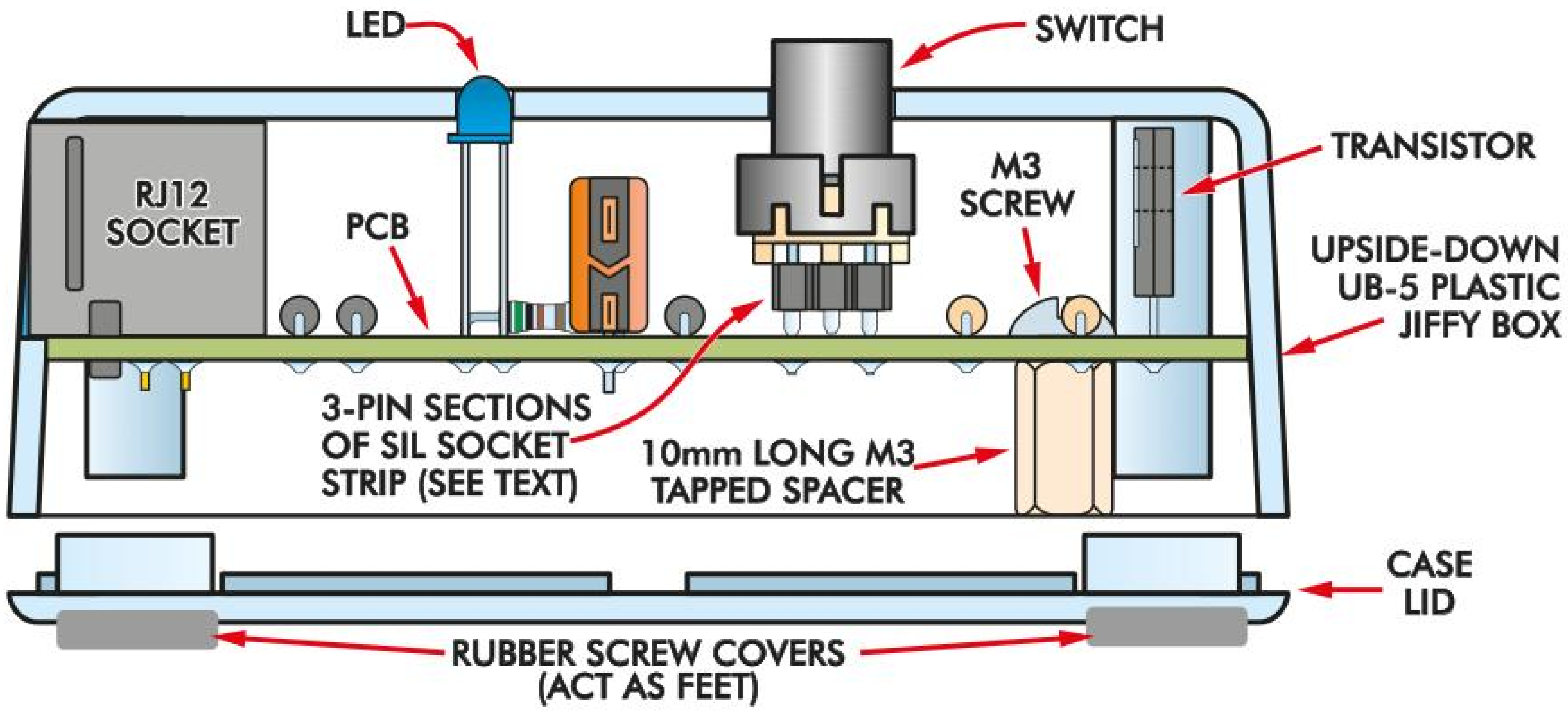

LED
SWITCH
RJ12 SOCKET
PCB
M3 SCREW
TRANSISTOR
UPSIDE-DOWN UB-5 PLASTIC JIFFY BOX
3-PIN SECTIONS OF SIL SOCKET STRIP (SEE TEXT)
10mm LONG M3 TAPPED SPACER
CASE LID
RUBBER SCREW COVERS (ACT AS FEET)

Fig.3: this diagram shows how it all goes together. The two switches are not soldered to the board, but mounted inside some cut-down DIL sockets. This gives them some 'play', making the board easier to fit in the case.

Where did these expressions come from?

We've talked about things like 'off hook' and 'on hook' in this article. You may also have heard expressions such as 'transmitter' and 'receiver' when phones are being described. But where did these expressions come from?

We thought we'd digress from our story with a little bit of telephone nostalgia!

Too long ago for most of us – but well within living memory for many – phones were rather different from what we have today. At right is a photo of an early wall phone, used on a manual telephone exchange (probably in the country) and this gives a good idea of where many of the terms came from.

There is a 'receiver' (or earpiece) hanging on a spring-loaded hook on the left side. It's 'on hook', it's ready to receive a call. Take the receiver off the hook to answer a call and, surprise surprise, it's 'off hook'. When the receiver is removed, the hook moves up and closes contacts inside the phone.

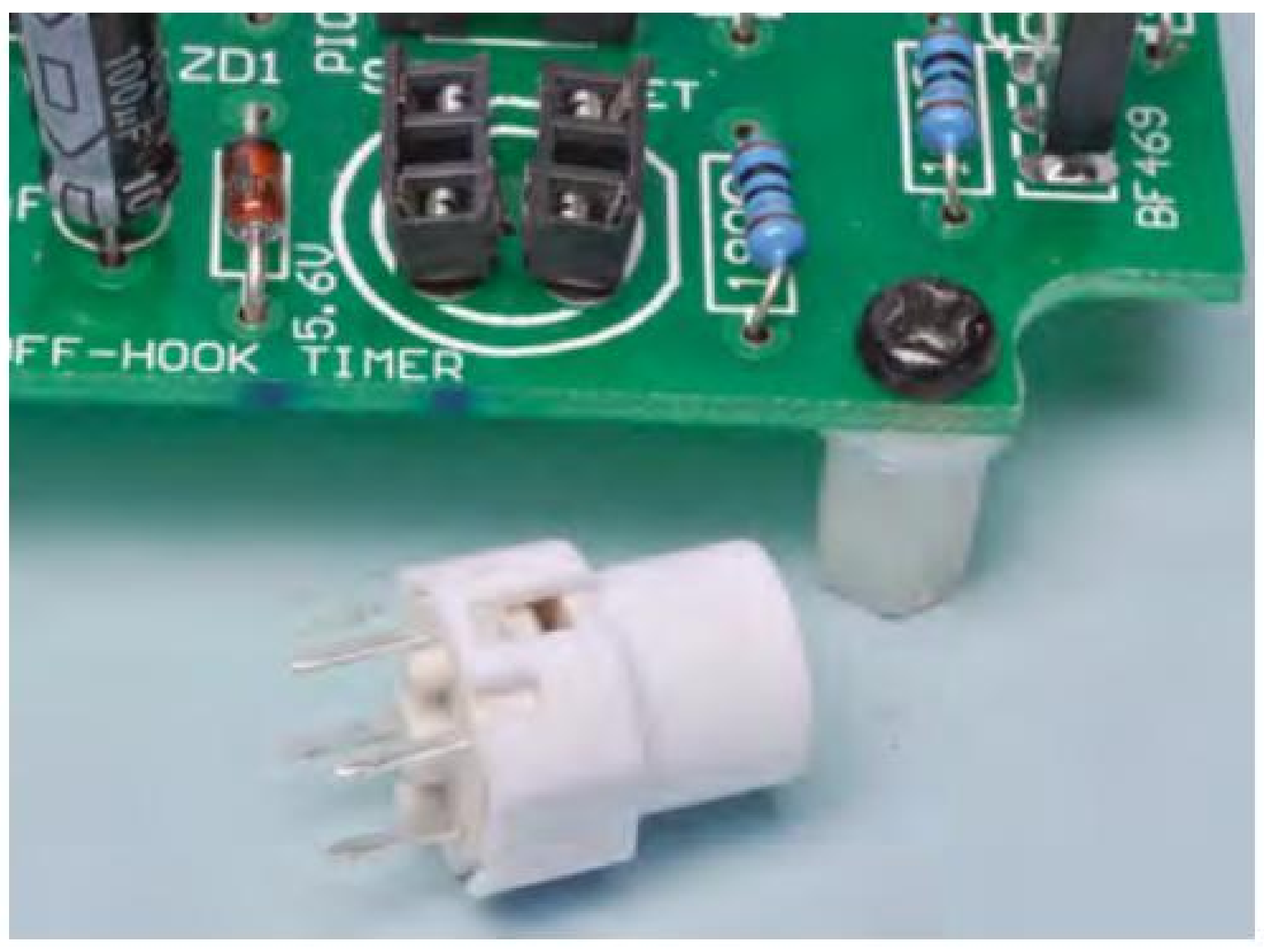
In the middle of the phone is the 'transmitter' (you may think of it as the mouthpiece) while just visible on right side is a handle which you turned vigorously to attact the attention of the telephionist, or switchboard operator. This handle was attached to a generator inside the phone which produced the voltage necessary to ring a bell at the exchange.

Such generators were in big demand by schoolboys of the day because you could generate enough voltage to give your mates a decent (though harmless) 'belt!'

In fact it was fun to arrange a ring of kids, all holding hands, with the generator connected to the last two in the ring so that all got the 'experience!'

Low voltage DC was provided by a couple of quite large 1.5V batteries (hence the size of the box in the pic above) – also prized by kids of the day and the cause of more than one public phone being out of action until they were replaced.

One final bit of trivia: city visitors (used to automatic exchanges) to homes in country towns with manual exchanges almost invariably picked up the handset, or receiver, before turning the generator handle. Of course, the phone recognised this as being 'off hook' and effectively shorted out the generator – so the exchange never answered. They couldn't understand why their country cousins always managed to make a call while they couldn't!



Here's a close-up of the way we mounted S1 and S2 in cut-down DIL sockets to allow easier assembly

5.6V. Now unplug the telephone line and insert IC1 making sure the orientation is correct. Reattach the telephone line and the *DO NOT DISTURB Timer* should operate when pressing the Set/Start button by showing the timer LED or LEDs.

You should be able to select the required time-out period by pressing the switch until the required setting is displayed. Then the time-out LED or LEDs should flash after about five seconds from when S1 is released.

If the LEDs do not light, check the orientation of IC1. Also check that Q1 and Q2 have been inserted in the right places (Q1 is the BF469 or MJE340 and Q2 is the BF470 or MJE350) with the correct orientation.

Enclosure

As mentioned earlier, we use the plastic box upside down, with the switches and LEDs protruding through the base of the box instead of the lid.

We've provided a panel label to print out (available on the *EPE* website).

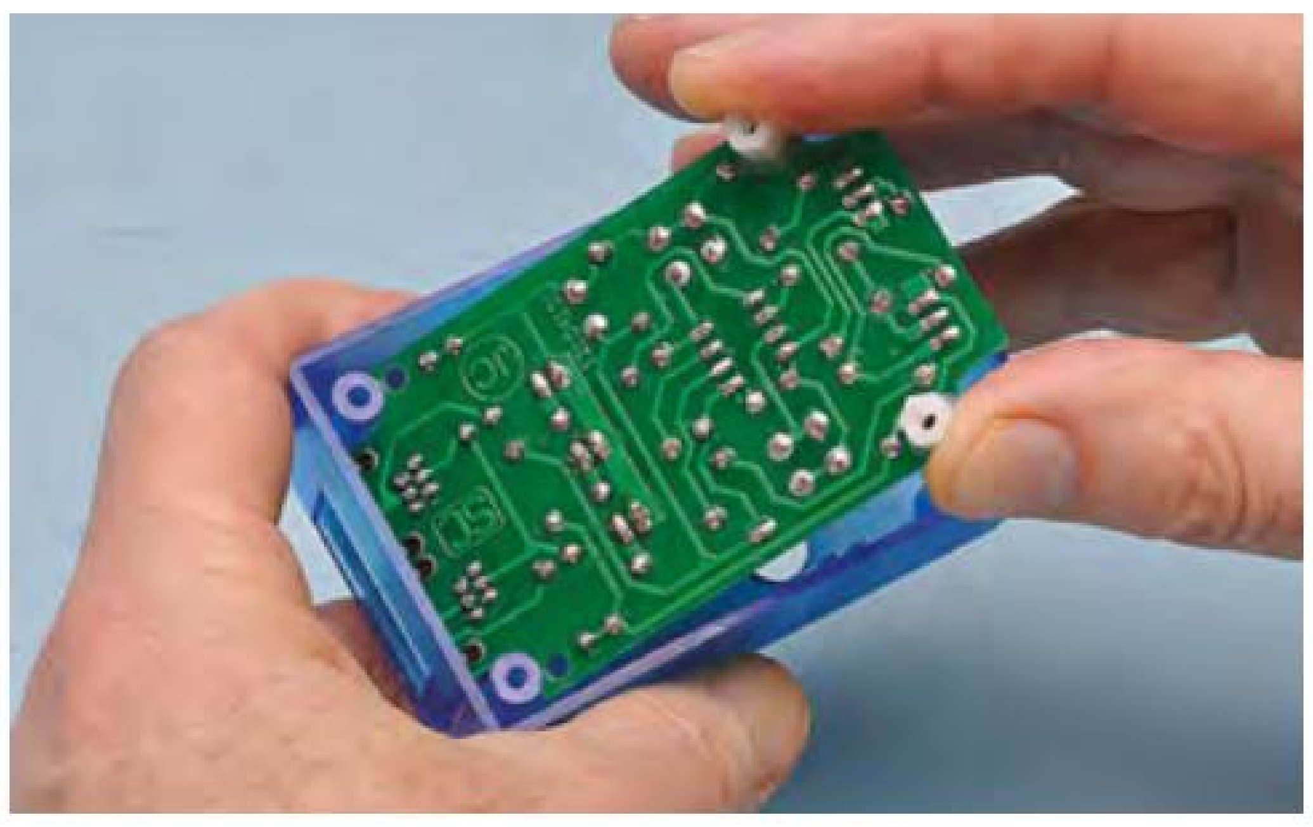
The RJ12 sockets protrude through a 27 × 15mm cutout in one end. The RJ12 sockets support the PCB in place at this end.

At the other end of the PCB, it is supported using two M3 tapped spacers. These spacers can be 10mm long or 9mm long with washers between the PCB and spacer to make up the extra 1mm length required.

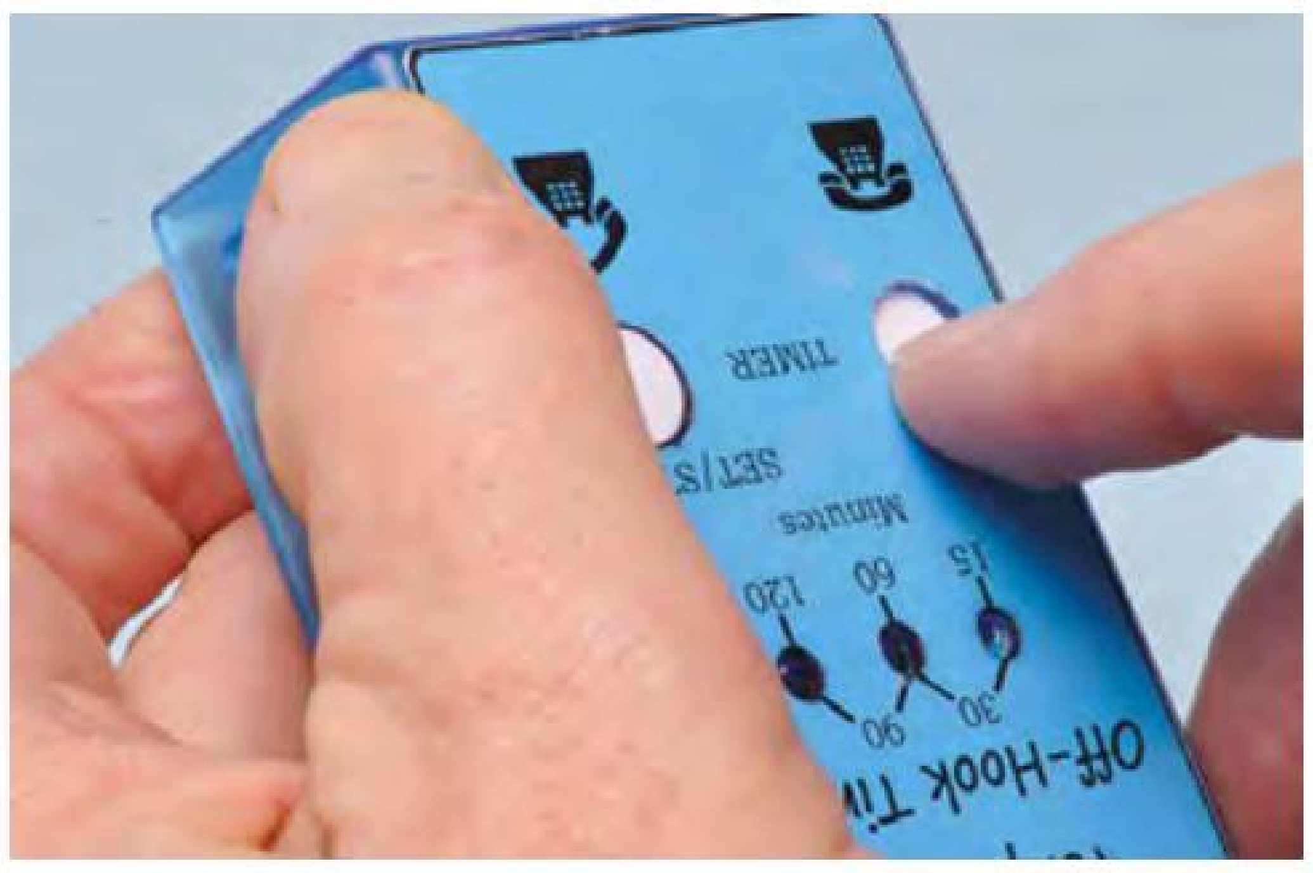
The spacers are secured to the PCB with M3 × 6mm screws. We did not secure the other end of the spacers to the box since the PCB is held in position with the transistors preventing upward movement. Fig.3 shows the arrangement.

Resistor Colour Codes

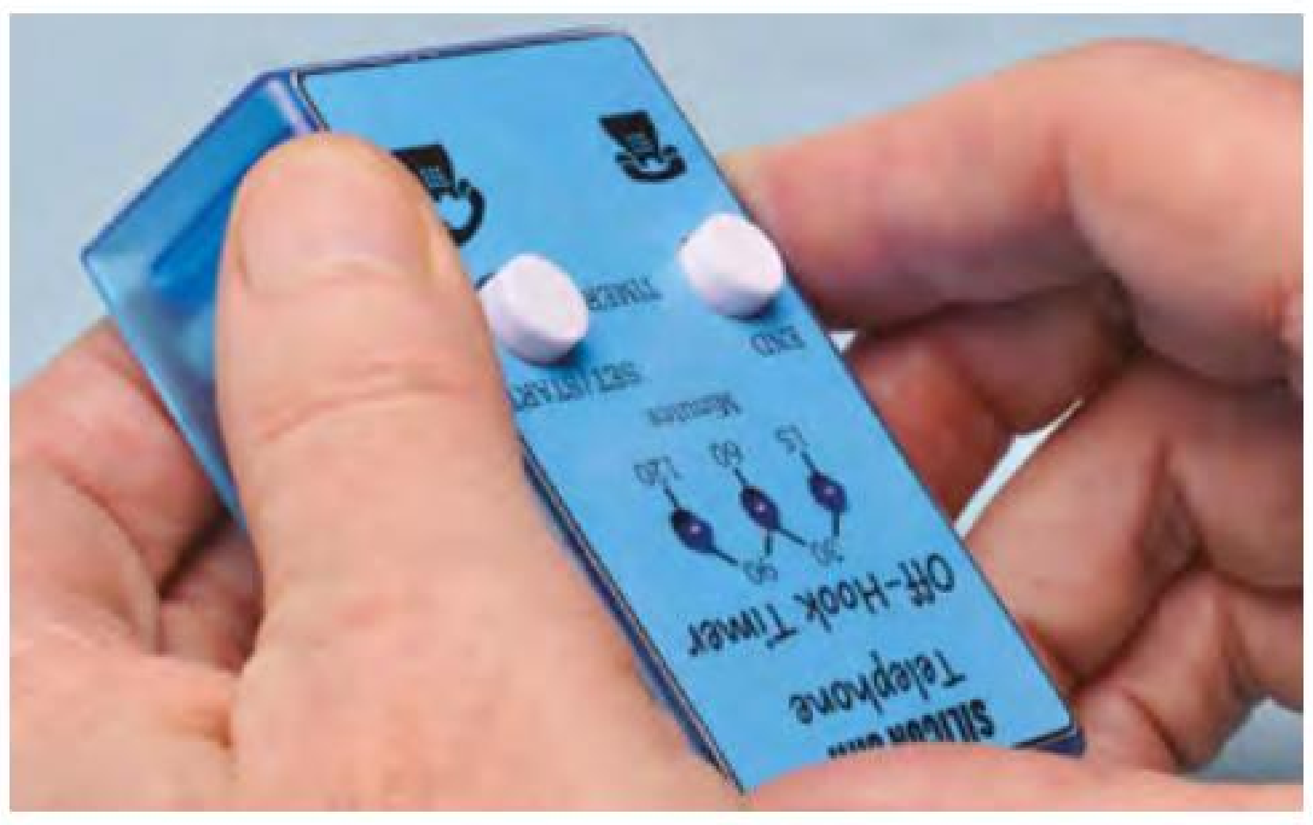
	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	100kΩ	brown black yellow brown	brown black black orange brown
☐	1	33kΩ	orange orange orange brown	orange orange black red brown
☐	2	10kΩ	brown black orange brown	brown black black red brown
☐	1	3.3kΩ	orange orange red brown	orange orange black brown brown
☐	3	1.5kΩ	brown green red brown	brown green black brown brown
☐	2	180Ω	brown grey brown brown	brown grey black black brown
☐	1	10Ω	brown black black brown	brown black black gold brown



Shoe-horning the PCB into the box: first slide the board in at an angle so the two RJ12 sockets fit in their cutout.



Next, jiggle the switch buttons a bit so that they emerge through the front panel (ie, case bottom!) holes.



And finally, push the PCB up from underneath so the pushbuttons and LEDs poke through the panel.

A diagram (Fig.4) is included, which shows the positioning of the rectangular cut-out in the end of the box for the RJ12 sockets. The front panel label can also be used as the template for the hole positions for the LEDs and switches.

Once drilled out, the front panel can be glued in with contact adhesive or silicone sealant. Once the adhesive has cured, the holes are cut out with a sharp hobby knife and filed with a rat-tailed needle file to clean up the panel edges.

The white edges of the photo paper inside the hole can be made less obvious by running a permanent black marker pen around the inside of the holes.

Inserting the PCB

So how do you insert the PCB into the box when it is used with the base of the box as the top panel?

There's an art to it, but once you've done it, you'll find it easy. Simply angle the two switches slightly forward (toward the RJ12 sockets). The switches can be angled because they are inserted into sockets and so can be easily moved. Tilt the RJ12 connector end of the PCB at an angle to first insert these connectors into the cut-out in the end of the box and then rotate the PCB to lie horizontal to the box base. The switches will then enter the holes in the box top. These switches can be seated correctly into their sockets by pressing them once the PCB is in place. The 10mm spacer prevents the PCB from dropping inside the box.

To connect up to the telephone, connect the telephone line plug into one RJ12 socket of the *DO NOT DISTURB! Timer* and use the extension RJ12 lead to connect between the other RJ12 socket on the *DO NOT DISTURB! Timer* and the telephone.

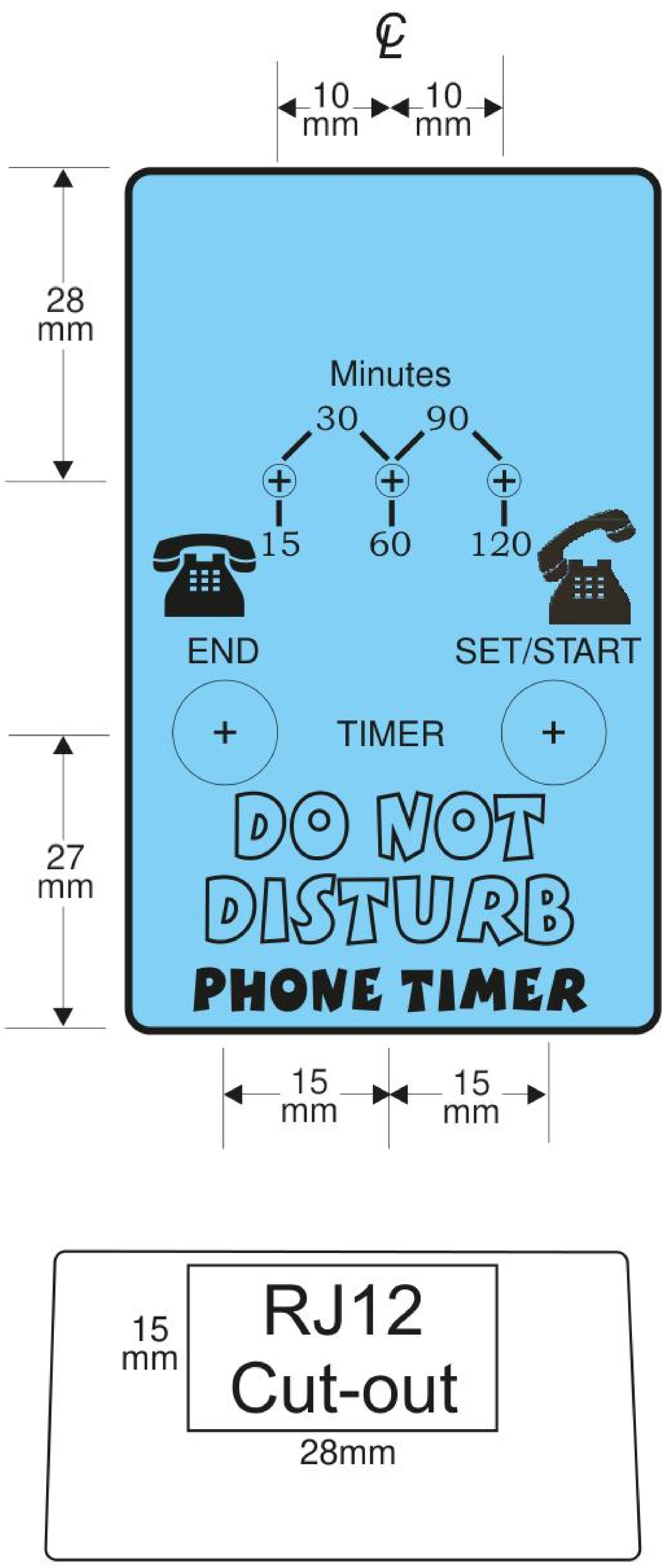


Fig.4: the front panel artwork and end-panel cutout diagram, which can be copied and used as a template. Both of these can be downloaed from the *EPE* website.

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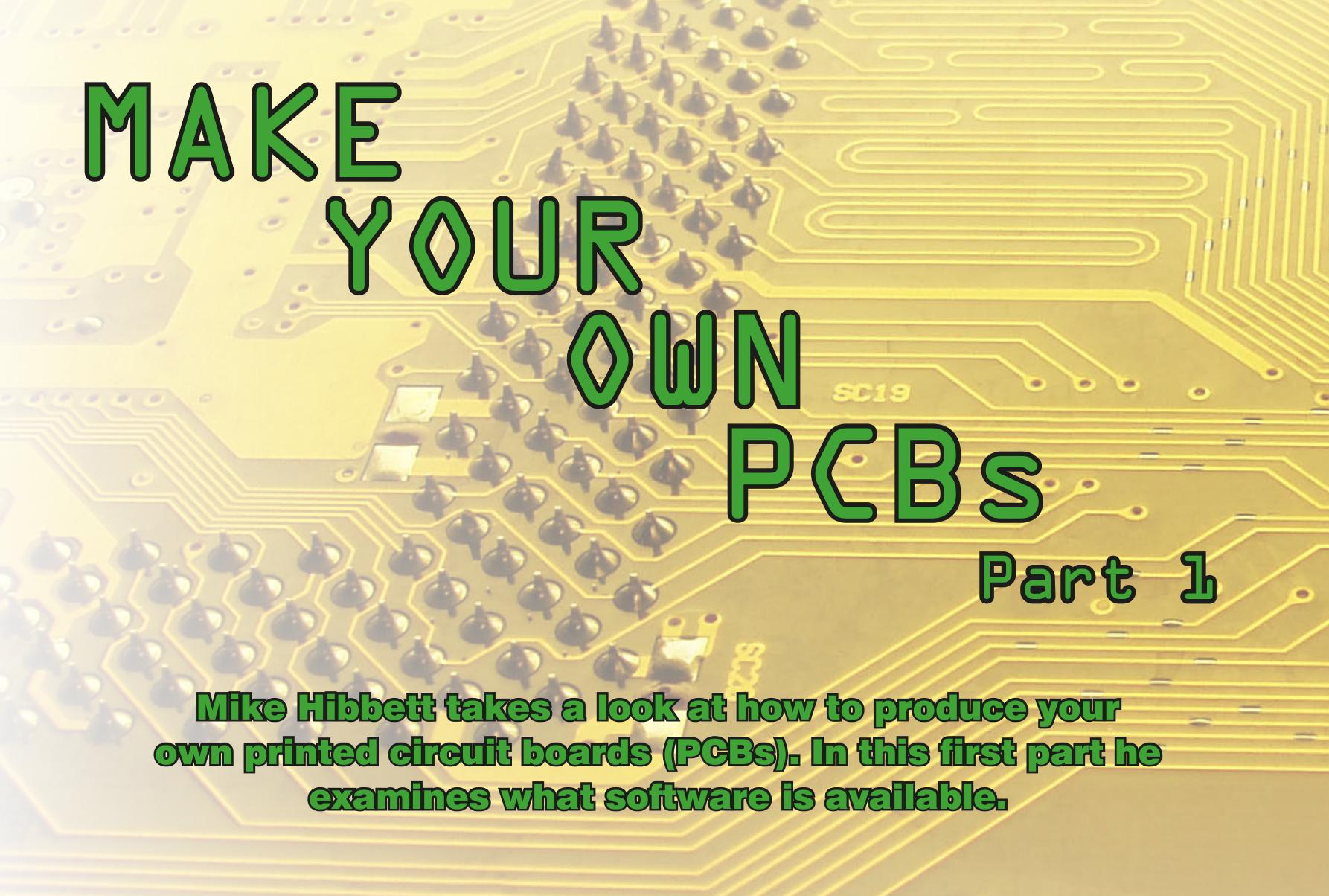


MAKE YOUR OWN PCBs

Part 1

Mike Hibbett takes a look at how to produce your own printed circuit boards (PCBs). In this first part he examines what software is available.

ONE of the most rewarding aspects of electronics as a hobby is creating something physical, that is durable and of high quality. We all have different standards and definitions that we work to (one person's idea of perfection might appear shoddy to others!) but generally we all strive to *do a good job*. For electronics hobbyists, that primarily means building a beautiful circuit board.

A circuit board is only one of many components when creating a project; there is also the issue of an enclosure, mechanical assembly, wiring, software and even perhaps artistic design if you are using a graphics LCD. They all have their own challenges, tools and pitfalls, and all deserve articles in their own right. In this series we are going to be looking at the processes involved in the creation of a printed circuit board; from design and generating data for professional manufacture through to purchasing boards. We will look at the entire 'development lifecycle' and uncover the wrinkles, surprises and unique pitfalls associated with PCB design. We make the mistakes, so you don't have to!

Professional PCB manufacture has become increasingly accessible to hobbyists in recent years, but manufacturers are still used to dealing with professional engineers, and so it can be a little daunting as a hobbyist to submit a design for production. There is a whole new language to conquer, with strange and exotic phrases such as 'acid traps', 'edge castellations' and 'electroless gold plating' to name a few. We will cover potential problems and hopefully provide you with the necessary information for you to make your first professional board a success. While it can be a little scary to part with perhaps fifty pounds for something that may not work, creating your own boards can be very satisfying. There is a wide range of options available for PCB manufacturing and you can use increasingly complex options as your skills and confidence grow, moving from single-sided through-hole designs up to double-sided, thin, surface mounts boards with complex profiles.

PCB manufacturers have a wide range of tools that can be brought to bear when making your board; gold plating, drills, routing and v-scoring to name a few. These tools and processes are largely computer controlled and automated, which means that there is little difference in cost between a square PCB with three holes drilled in it and one with a crazy outline and 50 holes. The main factor affecting cost is the PCB size, and the number of layers (a double-sided board is, to all intents and purposes, two single sided boards stuck together.) So it costs next to nothing to get creative with your designs. On top of that, the more boards you order the cheaper each part costs. So it pays to get your friends interested in a board or two at the same time.

The world's suppliers at your doorstep

Professional PCB manufacture used to be just that – for professionals only. You needed a business account and payment by credit card was a no-no. With the advent of the Internet and easy payment services such as Paypal (plus the relaxing of commercial terms for accepting credit card payments as a result of increased competition) it has become easier and easier for companies to work with hobbyists. With so many of us accessible through the Internet it became financially viable to provide boards and even modest design support services.

At first, a handful of PCB manufacturers around the world started offering hobbyist-specific PCB pool services, where the manufacturer places several customer designs on a single panel. Boards took a long time to come back (three to five weeks) but they were cheap. Increasing competition from Eastern Europe and the Far

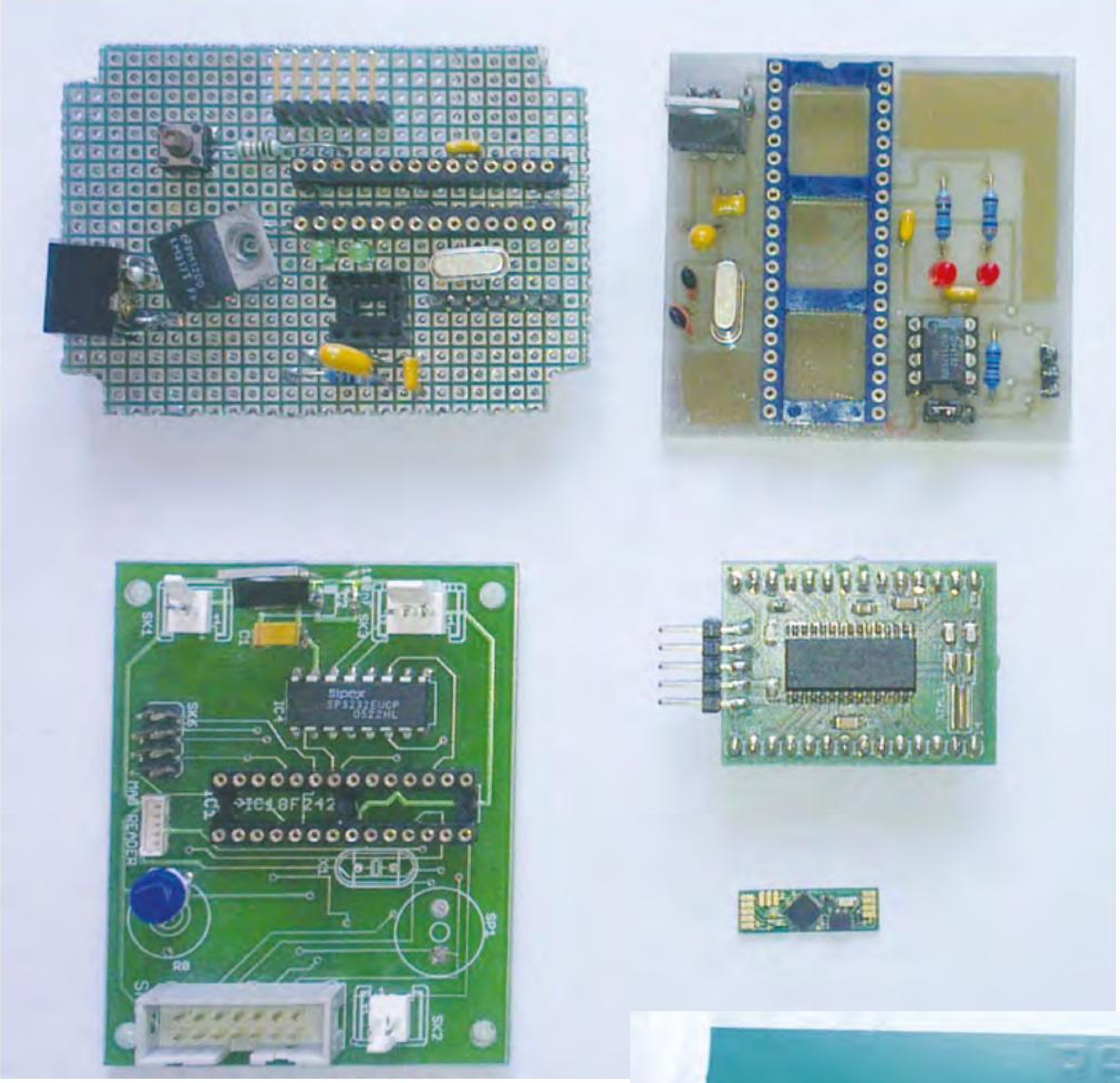


Fig.1. Evolution of the author's PCB designs

East reduced costs across the board (no pun intended!) and it is now *just about* cheap enough to make it routine.

PCB evolution

Fig.1 shows the evolution of the author's own board designs over the years. Top left is a hand-wired design built on a standard prototyping board (with the circuit design 'made up as we went along'.) Judging by the cut-outs in the corner section this board lived in a case once. With no original design – not even a note in a log book – we have no idea what this was used for!

Top right is an early CAD-assisted design, which was then hand etched. This board is about ten years old, and was part of a set of boards used to evaluate RS485 communication links. While designed with the aid of a CAD system – 'Boardmaker' most likely – it's evident that we had not mastered the use of 'copper flood fill' to reduce the amount of copper removed.

Bottom left is one of our first professionally manufactured boards, and features a number of design errors common to novices. There may be a prize for whoever spots the most flaws in that one!

In the bottom right section of the image you can see our more recent designs, using surface-mount technology. The tiny board measures just 6mm × 20mm and had to be assembled with the aid of a specialist PCB manufacturing microscope (40 times magnification) and a *very* steady hand.

While the PCB on the left was purchased in single quantities, the two boards on the right were purchased in bulk. When buying more than a dozen or so boards it makes sense to have the boards *panellised*, as shown in Fig.2. In panel format it is possible to fit the components more quickly, and perhaps make use of a reflow soldering process using an SMA (surface mount assembly) oven, as we discussed in an earlier article. When using an SMA oven to make your PCBs you must order an additional item from the PCB manufacturer, a solder stencil, as shown in Fig.3. This stencil is used to help with the placement of solder paste onto the board prior to placing components. The stencil adds about thirty pounds to the cost, but when you are ordering several hundred boards as we were here, it is an essential item and worth the price. This is an advanced option for PCB manufacturing and not something you are going to be interested in unless you are purchasing a large number of PCBs, but we thought you might like to see what you can do.

Article series

Over the coming months we will select a PCB CAD program, design a simple board, create manufacturing data and get some boards made. We start this

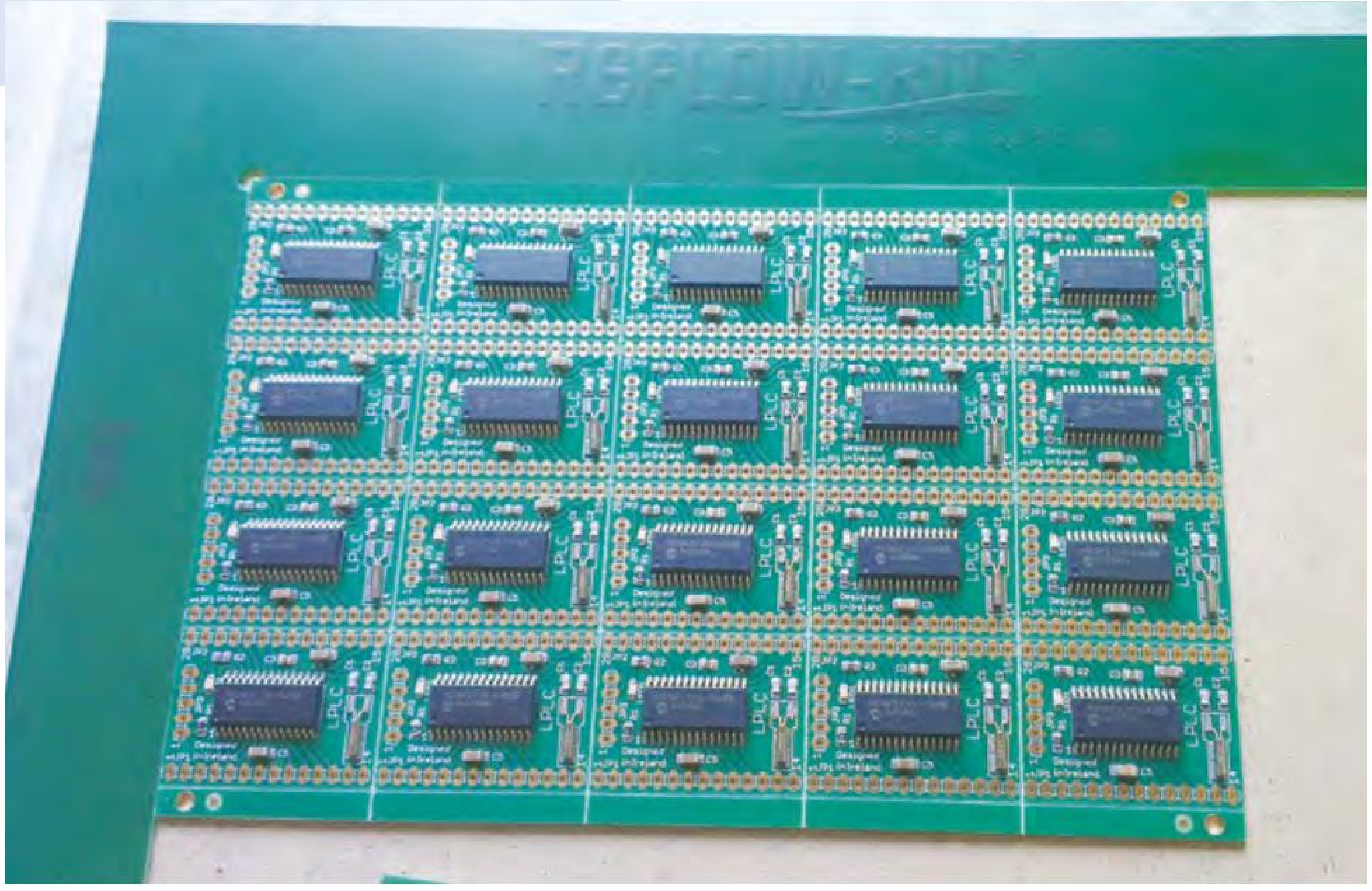
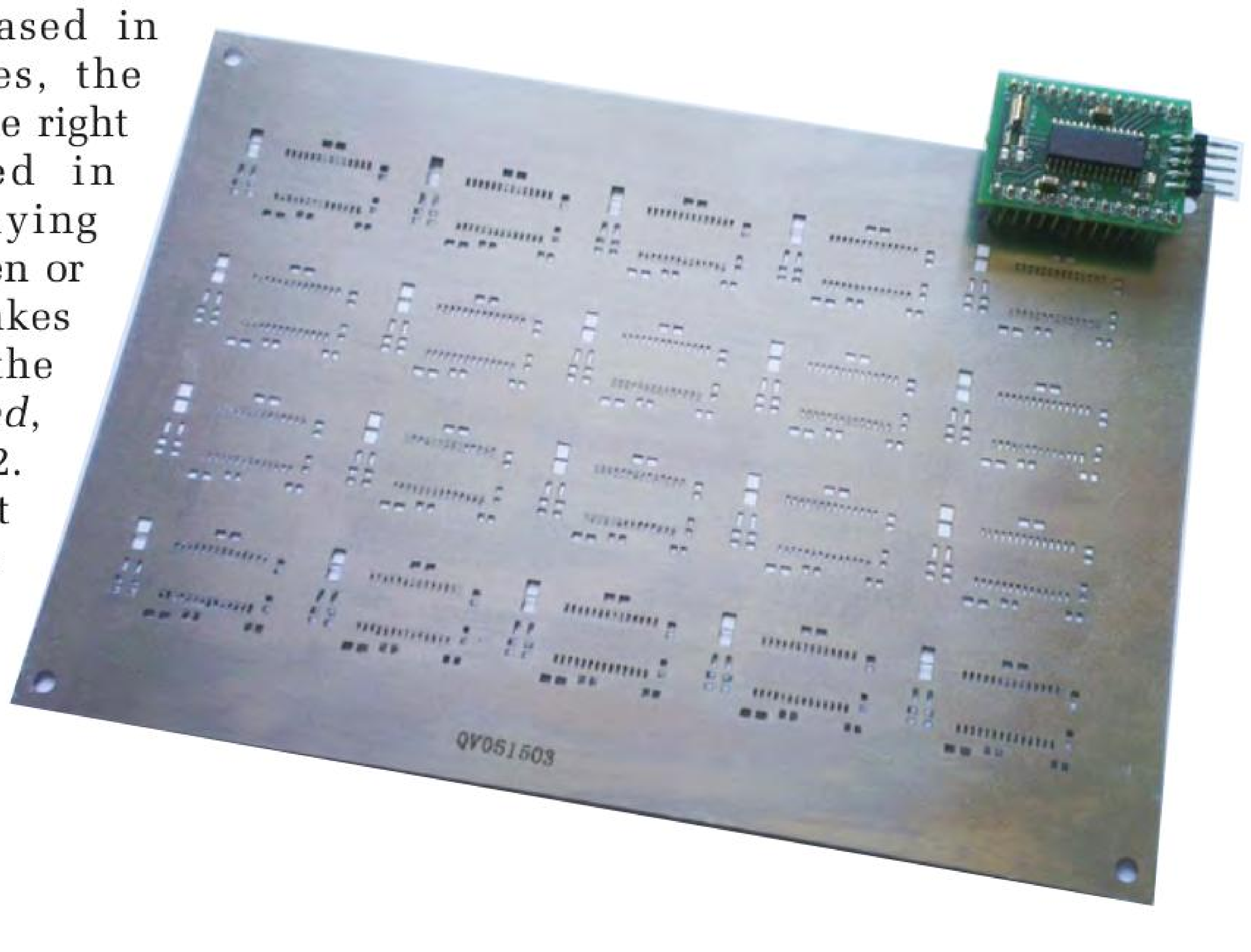


Fig.2. A panel of PCBs

Fig.3. Solder stencil



month by looking at the CAD programs available on the market and making a choice of which one to use in the rest of the article series. We try to be as objective as possible, but there will always be an element of subjectivity, so apologies if we have not selected your personal favourite CAD tool! If we haven't, or you decide to use a different one to ours, the principles described are exactly the same, so you won't be missing anything.

Next month, we will select a circuit design and start using the CAD tool to enter the schematic, verify it and prepare for the PCB layout in the following month.

CAD tools

So let's go ahead and select a CAD program. First, we need to decide on some selection criteria. These are ours:

1) The program should be cheap. We are hobbyists, after all.
2) It should run on the latest Windows PCs. Windows 7 and 8 are the most popular operating systems with our readers, so the program should run on at least those. If it runs under Linux (the author's preferred operating system) then all the better.
3) It should be reasonably easy to use. Professional CAD engineers use CAD software everyday. For those of us who 'dip-in' once in a while, the software should be easy to use or we will be constantly making mistakes.
4) It should be well supported. That means, there are lots of tutorials and help available on the Internet.

There are at least a dozen PCB CAD programs available on the market, and several of those are available for free (created as open source projects, so you can even modify the software itself.) Many of these programs can be dismissed due to being too expensive – anything costing more than a few hundred pounds is considered to be off limits, given that so much is available for little or no cost. At the other end of the cost scale, all bar one 'free' programs have been ignored simply because it is considered streets-ahead of the other free offerings.

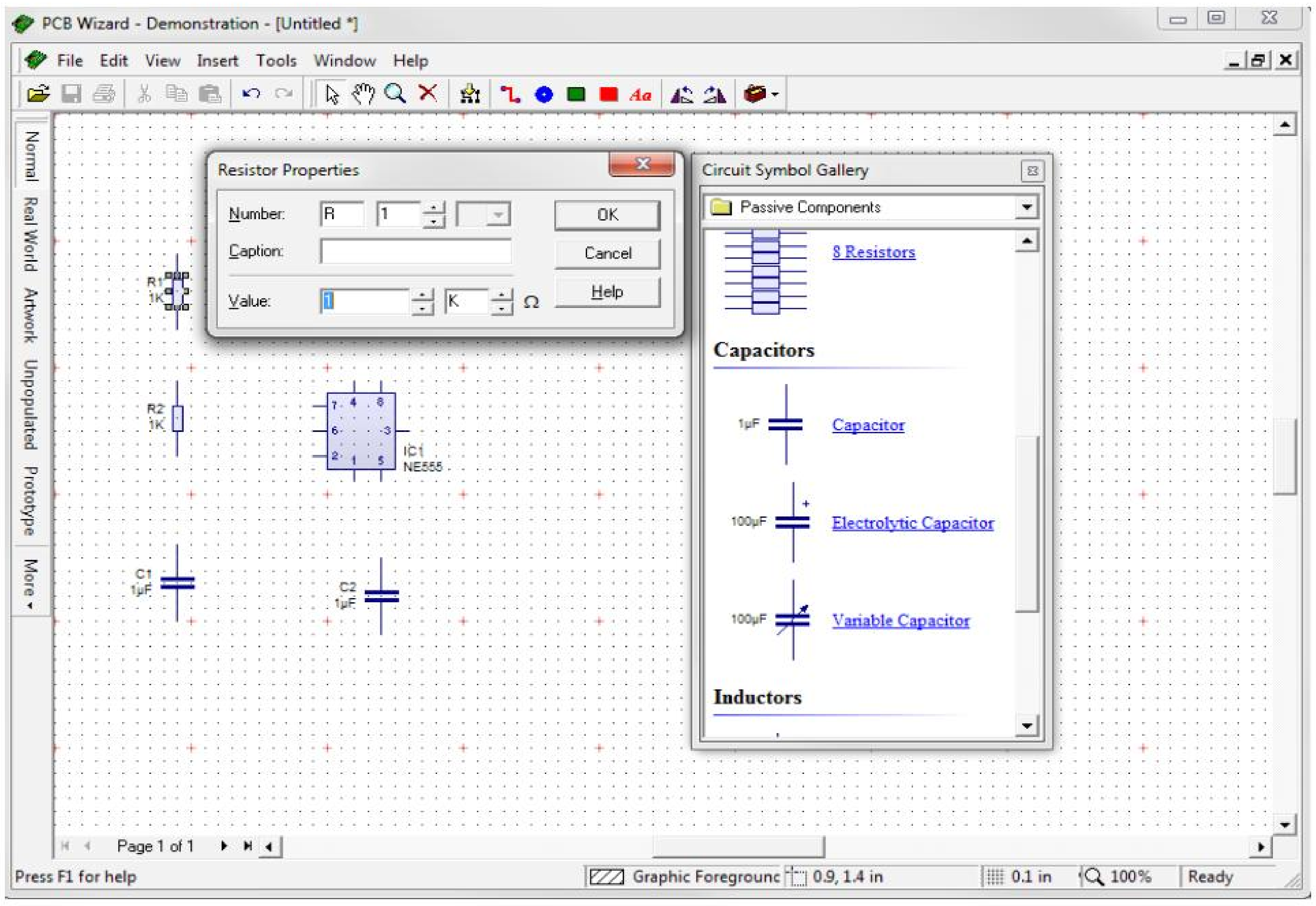
We whittled the list down to seven; five paid for, two commercial but 'free', and one 'Open Source'. (Open Source software makes not only the program free, but also its original design too, so anyone is free to change it. Although making changes to a program's source code is an unrealistic proposition for most people, it does mean that there is likely to be continued development of the program, and changes will be to the benefit of the users, not some corporate strategy.)

These programs all have their pluses and minuses, so lets take a look at them one by one.

The options

PCB wizard

PCB Wizard is a relatively cheap product at around fifty pounds and available for purchase from Maplins in the UK and Ireland. A very limited demonstration version is available for download that provides an insight into its capabilities, but you cannot do useful work with it. We found PCB Wizard to have a nice and simple user interface, as can be seen in Fig.4. It's an easy to use program for simple designs, but lacks surface mount component support, which is something of a surprise in this day and age. Surface mount components are becoming more popular and easy to purchase, so their omission is difficult to overlook. It's a fun program to use, but we will pass on it this time, as anyone using it would quickly surpass the program's capabilities.



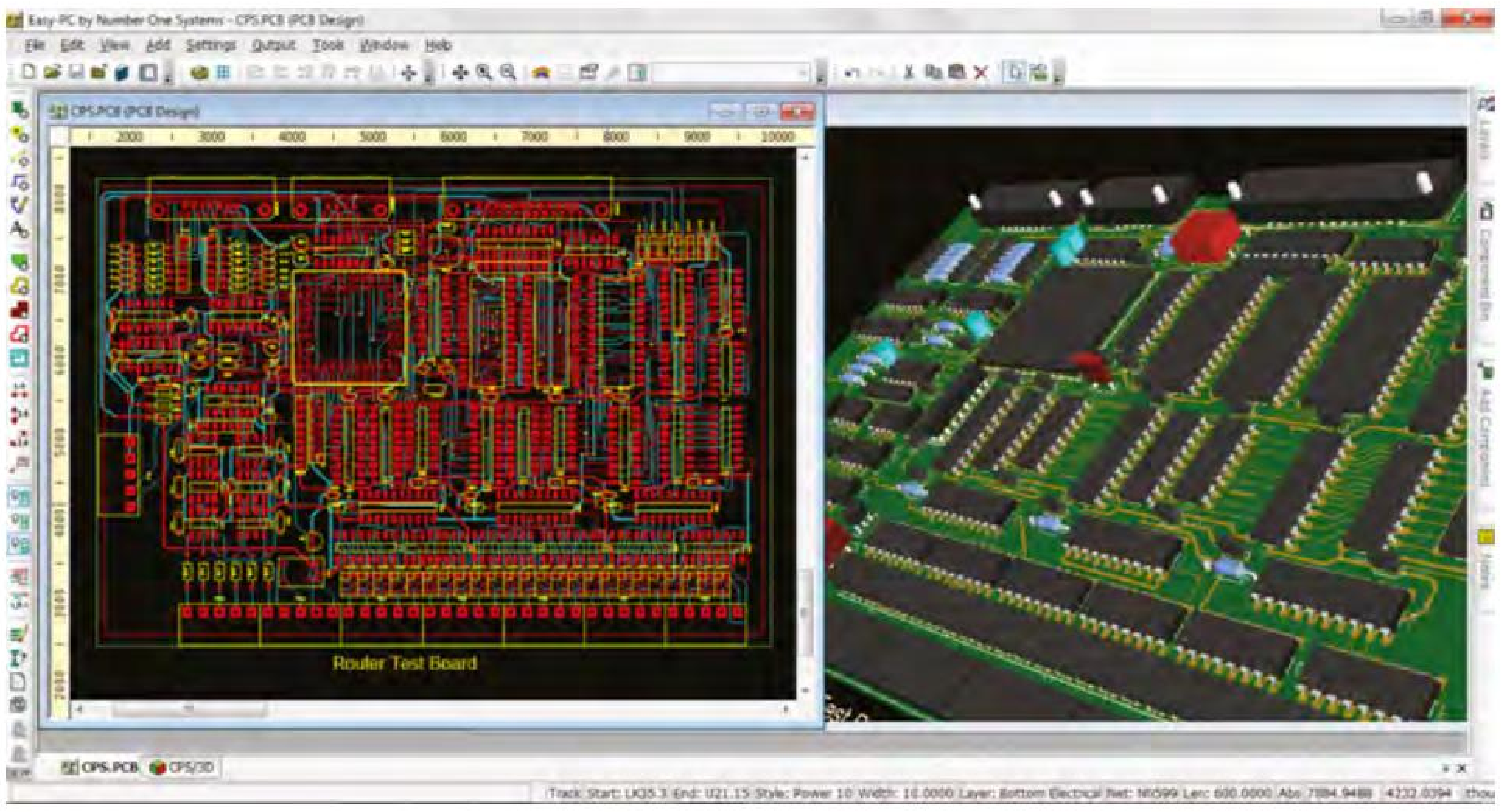
Number: R 1
Caption:
Value: 1 K Ω

PCB Wizard - Demonstration - [Untitled *]
File
Edit
View
Insert
Tools
Window
Help
Normal
Real World
Artwork
Unpopulated
Prototype
More
Resistor Properties
OK
Cancel
Help
R1
1K
R2
1K
IC1
NE555
C1
1µF
C2
1µF
Circuit Symbol Gallery
Passive Components
8 Resistors
Capacitors
1µF
Capacitor
100µF
Electrolytic Capacitor
100µF
Variable Capacitor
Inductors
Page 1 of 1
Press F1 for help
Graphic Foregrounc
0.9, 1.4 in
0.1 in
100%
Ready

Fig.4. PCB Wizard

Easy-PC

Created by Number One Systems in the UK, Easy-PC is clearly targeted at professional users, and this is reflected in the price. A cheaper, pin-count limited version is available – limited to 1000 pins on the board – but this sells for £250, so is just a little outside our price limit. It includes a fast 3D viewer (as you can see in Fig.5) and is clearly a more appropriate tool for our needs, just too expensive for hobbyists. Remember, these tools will be pitched against free programs.



Easy-PC by Number One Systems - CPS.PCB (PCB Design)
File
Edit
View
Add
Settings
Output
Tools
Window
Help
CPS.PCB (PCB Design)
Router Test Board
CPS.PCB
CPS/3D

Fig.5. Easy-PC

Design spark PCB

Design Spark PCB is branded and distributed by RS Components, but is actually produced by Number One Systems, the people who make Easy-PC. It's no surprise then that the two have a similar look and feel (which is a good thing.) Unlike Easy-PC, Design Spark PCB is completely free although it is still proprietary code, and you have to register with RS Components to unlock some of the features. It's laden with adverts for RS Components, but that is a small price to pay for something that is free, and very useful. It has some professional features, such as automatic routing of signals and even automatic placement of components.

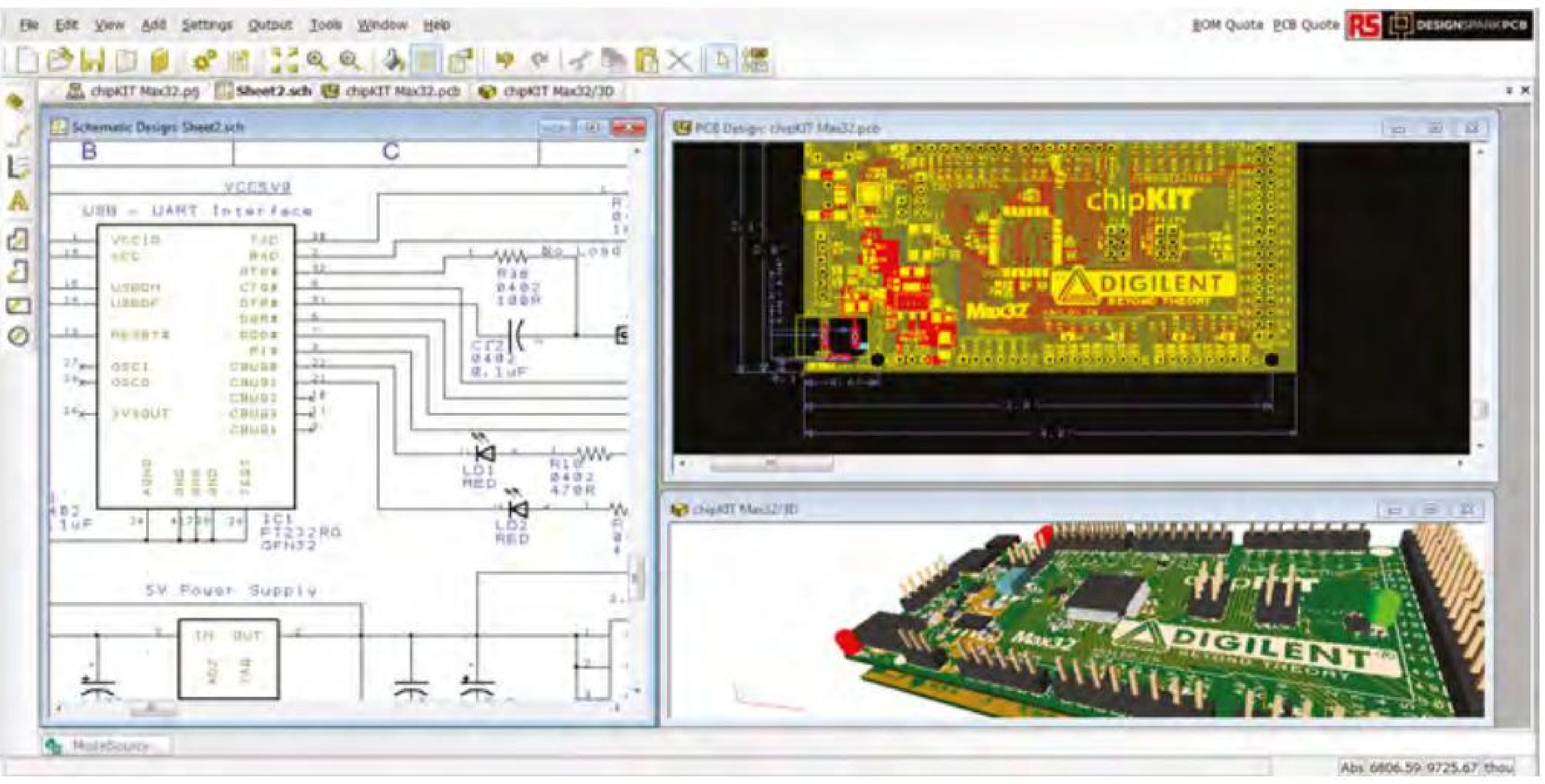

File Edit View Add Settings Output Tools Window Help
BOM Quota PCB Quote
DESIGNSPARK PCB
chipKIT Max32.pcb
Sheet2.sch
Schematic Design: Sheet2.sch
PCB Design: chipKIT Max32.pcb
chipKIT Max32/3D
USB – UART Interface
5V Power Supply
chipKIT
DIGILENT
Max32

Fig.6. Design Spark

There is no support for Linux operating systems (which a growing number of hobbyists are using these days) and overall we found the tie-in to RS Components a little annoying. It's certainly worth a look, and there is a reasonable level of support available on the Internet, though not the best.

Express PCB

Express PCB is another proprietary program supplied free of charge, this time by the PCB manufacturer ExpressPCB. Not a terribly original name for their program!

It appears to be a halfway solution between the simple, hobbyist-oriented tools and professional solutions. It runs only under Windows, has limited features and a limited (but usable) component library. In its favour is its integration with the PCB manufacturer; once you have completed a PCB design, a few button clicks sends the data to ExpressPCB for a quote. There are no complex steps required to generate the manufacturing data. This also works against it; the data you create can be processed by ExpressPCB alone, locking you into them as a supplier. As they are not cheap, nor have many manufacturing process options, this is a bad thing. We rejected them on that simple point alone.

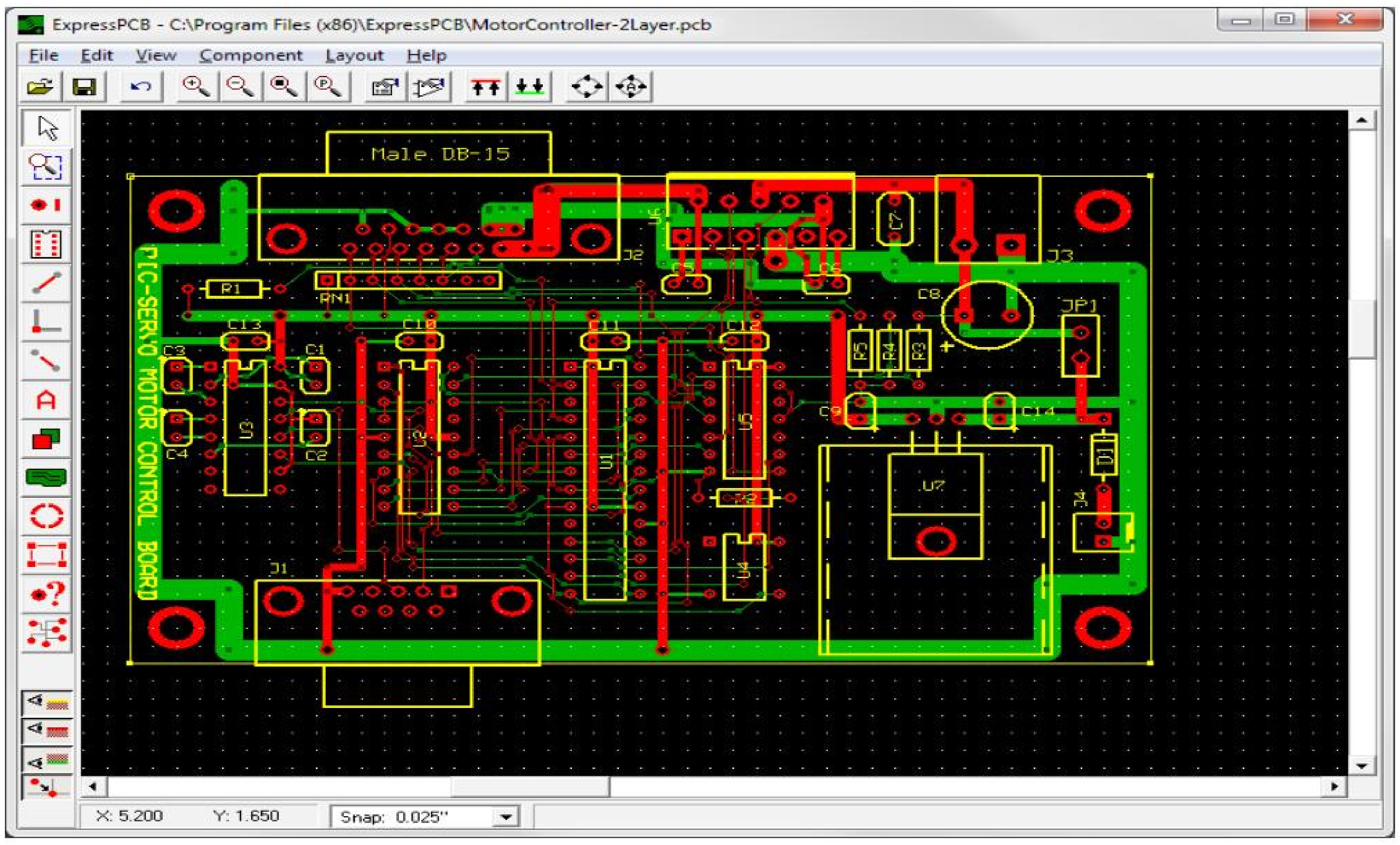
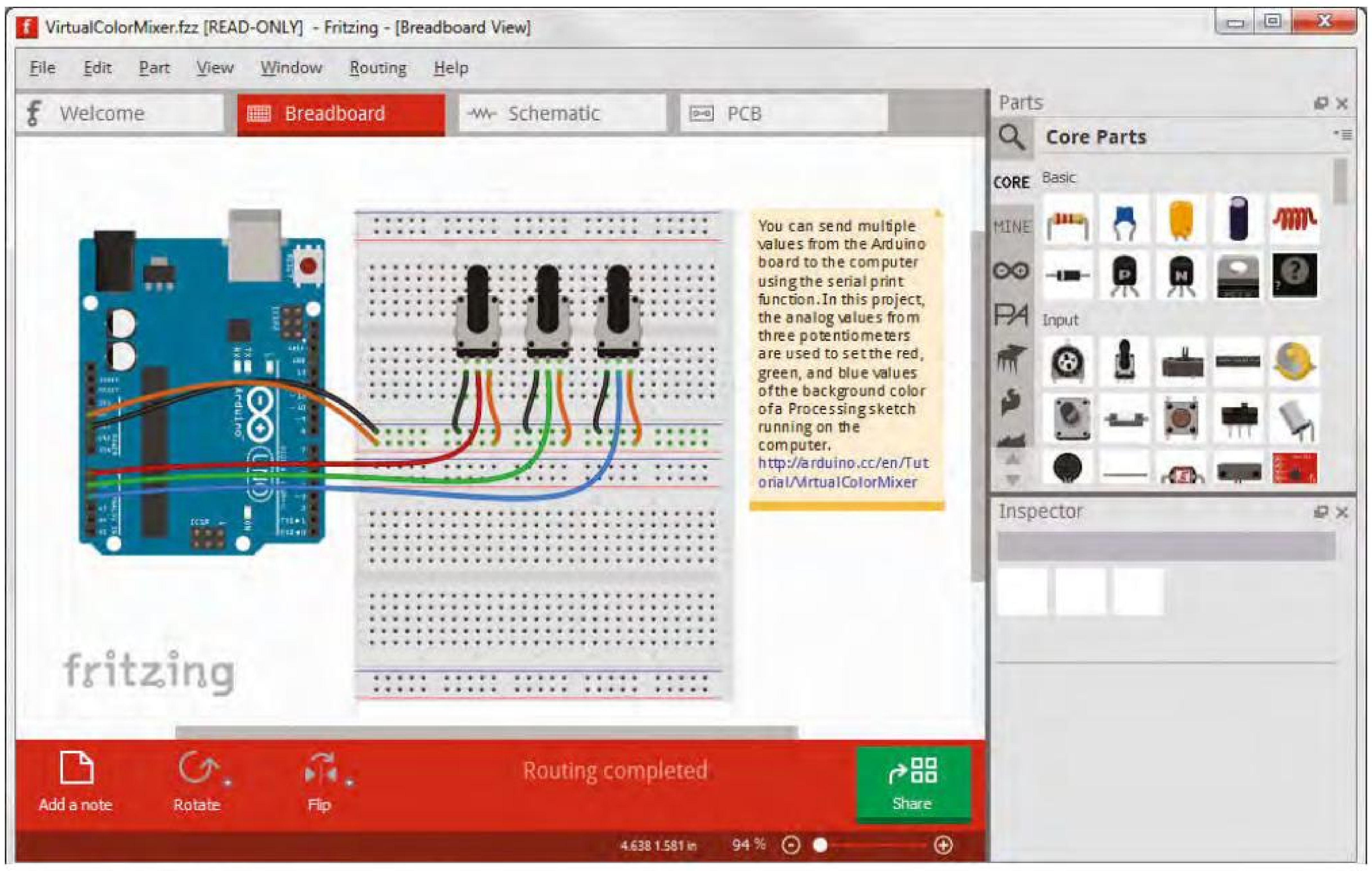

ExpressPCB - C:\Program Files (x86)\ExpressPCB\MotorController-2Layer.pcb
File Edit View Component Layout Help
Male DB-15
PIC-SERVO MOTOR CONTROL BOARD
X: 5.200
Y: 1.650
Snap: 0.025"

Fig.7. Express PCB

Fritzing

Fritzing is a fun and easy to use program, the software is open source, and it runs on Windows, Linux and Mac PCs. It already presses all of our buttons! You can see one of its simpler examples in Fig.8.

It's geared specifically towards hobbyists and is not really a PCB design tool but can be used to create all kinds of designs based on PCB, Veroboard or breadboard. The visuals are *beautiful* and easy to understand – so they are great for producing designs to be re-used by other people. Designs can be translated into physical boards, but the options are limited. It is huge fun to play with though, and from just a few hours playing with it we have become hooked. Expect to see images created by Fritzing in future *Pic n' Mix* articles!


VirtualColorMixer.fzz [READ-ONLY] - Fritzing - [Breadboard View]
File Edit Part View Window Routing Help
Welcome
Breadboard
Schematic
PCB
Parts
Core Parts
CORE
Basic
MINE
Input
Inspector
fritzing
Add a note
Rotate
Flip
Routing completed
Share
4.638 1.581 in
94 %

You can send multiple values from the Arduino board to the computer using the serial print function. In this project, the analog values from three potentiometers are used to set the red, green, and blue values of the background color of a Processing sketch running on the computer. http://arduino.cc/en/Tutorial/VirtualColorMixer

Fig.8. Fritzing

Eagle

Eagle is something of a hybrid; it is available for free for use with boards sized under 80mm × 100mm, and the paid versions start at just outside our budget. It provides all the usual professional features (as expected of a CAD package that costs under £1000) and is, in the author's view, very easy to use. We have used it for over ten years and have yet to be teased away to another program. It comes with a good autorouter (although an automated component placement option would have been nice.) Just as RS Components supports Design Spark, so Farnell have jumped on the bandwagon and put their weight behind EagleCAD. Their input to EagleCAD is subtle, however – a simple link in the user interface, and the addition of Farnell part numbers to the component symbols. This is a very useful feature, as it simplifies the creation of parts lists.

EagleCAD appears to be very popular on the Internet. There are thousands of links to tutorials on all subjects relating to its use, and the likes of AdaFruit, SparkFun and others often publish their open source hardware designs in EagleCAD format. As do many hobbyists too.

It's available for Linux too, ticking another of our boxes. The EagleCAD user interface can be seen in Fig.9.

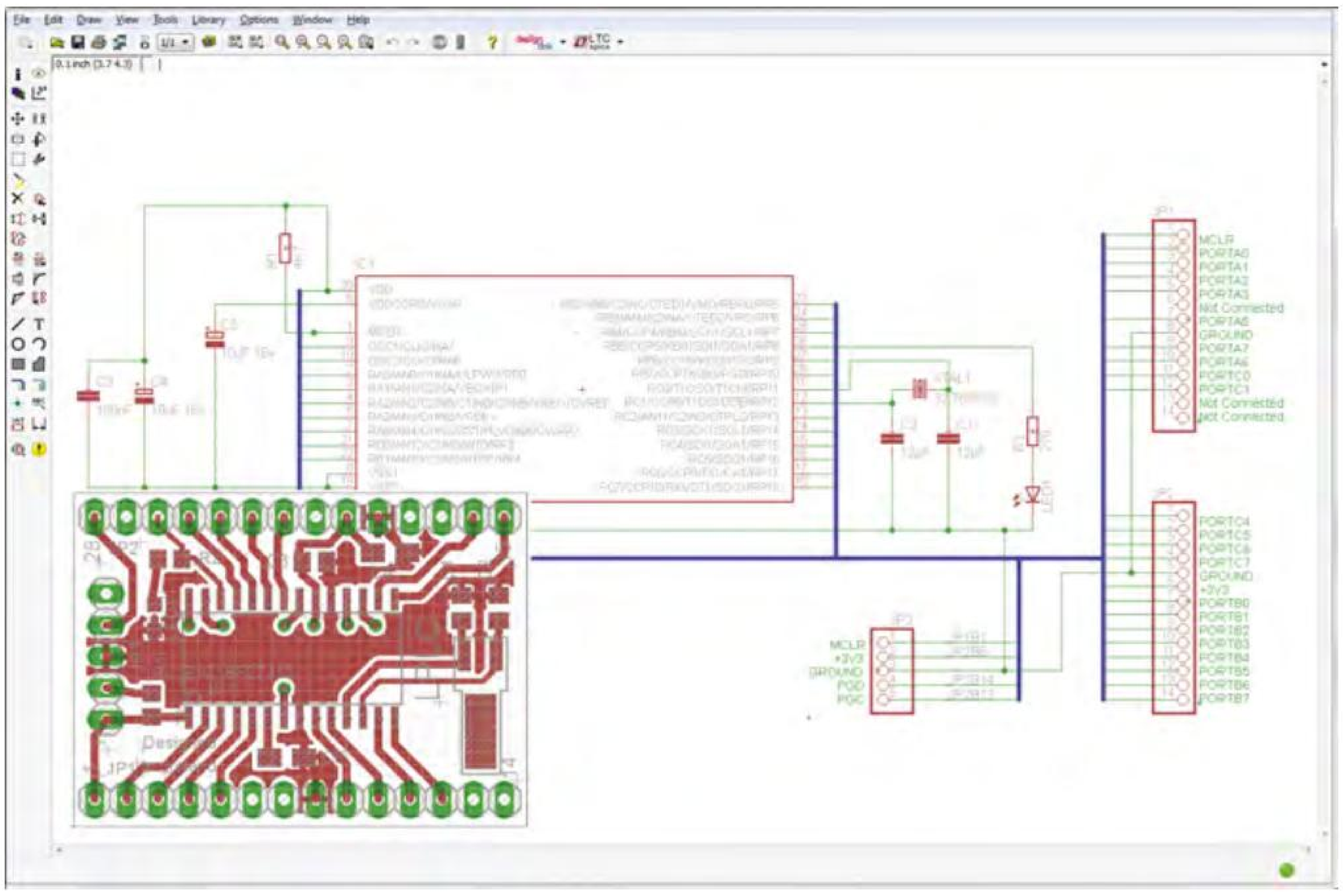


Fig.9. EagleCAD

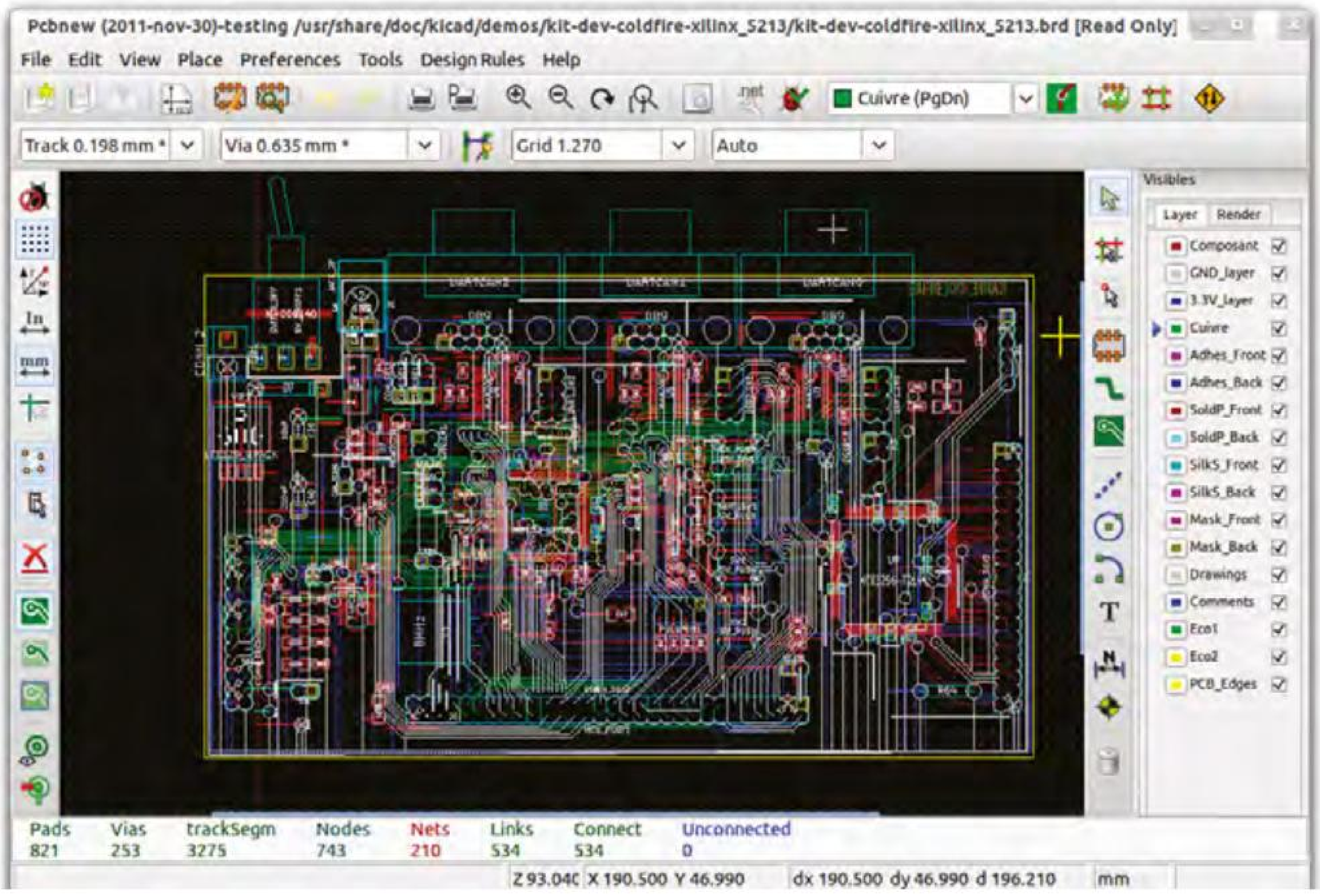
KiCAD

KiCAD is the only Open Source CAD program to make our list. The reason for this is simple: it is streets ahead of other free programs, and ahead of many expensive commercial versions too. It aims to be a professional solution, and makes no effort to be easy to use, or friendly towards hobbyists. You can see a complex design in the KiCAD user interface in Fig.10.

KiCAD comes with a simple autorouter and a basic 3D viewer capability, and its component library is good (although perhaps not as good as EagleCAD.) As with the other programs it is possible (and normal) to create symbols yourself; it's just that it's nice to have these already available, especially when one is new to the program and unfamiliar with its use.

KiCAD has its supporters in the industry, including the PCB and Development board manufacturer Olimex, which wants to see a non-proprietary CAD program become the tool of choice.

KiCAD is the most likely tool to entice the author away from EagleCAD, yet each time we try, the steep learning curve (and the need to create custom symbols that are already available for EagleCAD) has put us off.


Pcbnew (2011-nov-30)-testing /usr/share/doc/kicad/demos/kit-dev-coldfire-xilinx_5213/kit-dev-coldfire-xilinx_5213.brd [Read Only]

Cuivre (PgDn)

Track 0.198 mm * | Via 0.635 mm * | Grid 1.270 | Auto

Composant ☑
GND_layer ☑
3.3V_layer ☑
Cuivre ☑
Adhes_Front ☑
Adhes_Back ☑
SoldP_Front ☑
SoldP_Back ☑
SilkS_Front ☑
SilkS_Back ☑
Mask_Front ☑
Mask_Back ☑
Drawings ☑
Comments ☑
Eco1 ☑
Eco2 ☑
PCB_Edges ☑

Pads	Vias	trackSegm	Nodes	Nets	Links	Connect	Unconnected
821	253	3275	743	210	534	534	0

Z 93.040 X 190.500 Y 46.990 dx 190.500 dy 46.990 d 196.210 mm

Fig.10. KiCAD

Conclusion

There are several programs that stand out in this group; KiCAD for being completely free and very powerful, EagleCAD for being very popular and free (with some limitations) and Fritzing, which is not really designed for PCB creation, yet is a fantastic tool for *other* uses.

In the end, however, we are going to go with EagleCAD. Its easy to use, popular, has many tutorials available and a large component library. Board sizes are limited to 100mm × 80mm for the free hobbyist version, but if you need to design larger boards than this then the learning curve with KiCAD will not be such a concern.

We explore the language of PCB design next month, and lay down some of the key concepts *before* starting on a PCB design proper the following month. Until then, why not download EagleCAD and have a play, perhaps watch some tutorial videos before we dive into the subject in detail.

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The mystery of component markings

THE amount of writing to be found on electronic components varies considerably from one type to another. Most resistors and a few other components use colour coding to indicate the value and other parameters, and carry no alphanumeric characters at all. However, apart from resistors it is the norm for components to be marked with the value or type number in written form, probably with other information that is appropriate for the type of component in question. A capacitor for example, will usually be labelled with its maximum operating voltage and tolerance rating in addition to its capacitance value.

Blind date

You will find with some components that there are additional markings that do not seem to make a great deal of sense. There could also be a value or type number that is not as expected. Taking the extra markings first, these sometimes give additional information about the component, such as temperature coefficient or maximum temperature rating, but in most cases anything of this type is not of any practical significance unless you are designing your own circuits. Even then, the extra information provided will be of little practical interest.

In most cases the additional markings are of no importance. They are often things like batch numbers, the manufacturer's name or logo, and date codes. Many manufactured goods, and not just electronic components, are marked with the date of manufacture. This is unlikely to be in day-month-year form, or anything of this ilk. It is more likely to be in a more cryptic form, such as the number of days since the factory where it was made started production, or the number of days that the factory had been in production. Sometimes there will be a few letters and numbers that indicate the particular plant where the component was produced, and the year of production. Again, the year is likely to be in an obscure form, with the letter 'A' perhaps being used for the first 12 months of production, the letter 'B' for the next 12 months, and so on.

Anything of this type is meaningless to anyone other than those 'in the know' who work for the manufacturer. It is also likely to be of no help whatever to the end user. Just the opposite in fact, and you have to learn to 'separate the wheat from the chaff'. Find the value or other information that is needed and ignore any other markings.

Best before

Some electrolytic capacitors are marked with the date of manufacture in a more normal form. This seems to be less common than was once the case, and it is something that has only ever been commonplace with higher value and (or) high voltage components. It is the capacitor version of a 'use by' or 'best before' date, although the marked date is usually indicates when the component was made rather than when it is likely to fail. Electrolytic capacitors tend to deteriorate with age faster than most other components, due to a decline in the potency of the electrolyte in the dielectric. The problem is simply that the electrolyte gradually evaporates.

Electrolytic capacitors can fail in spectacular fashion, but that is not really a problem when deterioration due to aging occurs. Electrolytic capacitors tend to go lower and lower in value as they gradually fade away, rather than 'going out with a bang'. Old audio and radio equipment often suffers from excessive 'mains hum' because the smoothing capacitors have lost much of their value and are not smoothing the supply properly. I have a couple of old electronic flashguns that appear to work perfectly, but their 'tired' capacitors only provide about half the output they used to.

The operating life of an electrolytic capacitor is dependent on temperature, with higher temperatures giving greatly reduced lifespan. The manufacturer's data will usually indicate an operating life of 10 years or more at room temperature, but at higher temperatures it could be just a few thousand hours. Presumably this is the reason for a date of manufacture being given instead of a 'replace by' date. The operating life is largely dependent on the operating conditions. Anyway, I would guess that most items of electronic equipment become obsolete long before the electrolytic capacitors they contain deteriorate to a significant degree. If you should happen to obtain some electrolytic capacitors marked with dates from long ago, perhaps in a 'bargain bundle' of components, it is probably best not to use them.

Electrolytic capacitors are sometimes marked with a temperature, or perhaps two temperatures (Fig.1). These simply indicate the maximum operating temperature, or the maximum and minimum working temperatures. Going outside the safe operating range can result in a component failing due to the electrolyte freezing or rapidly evaporating.

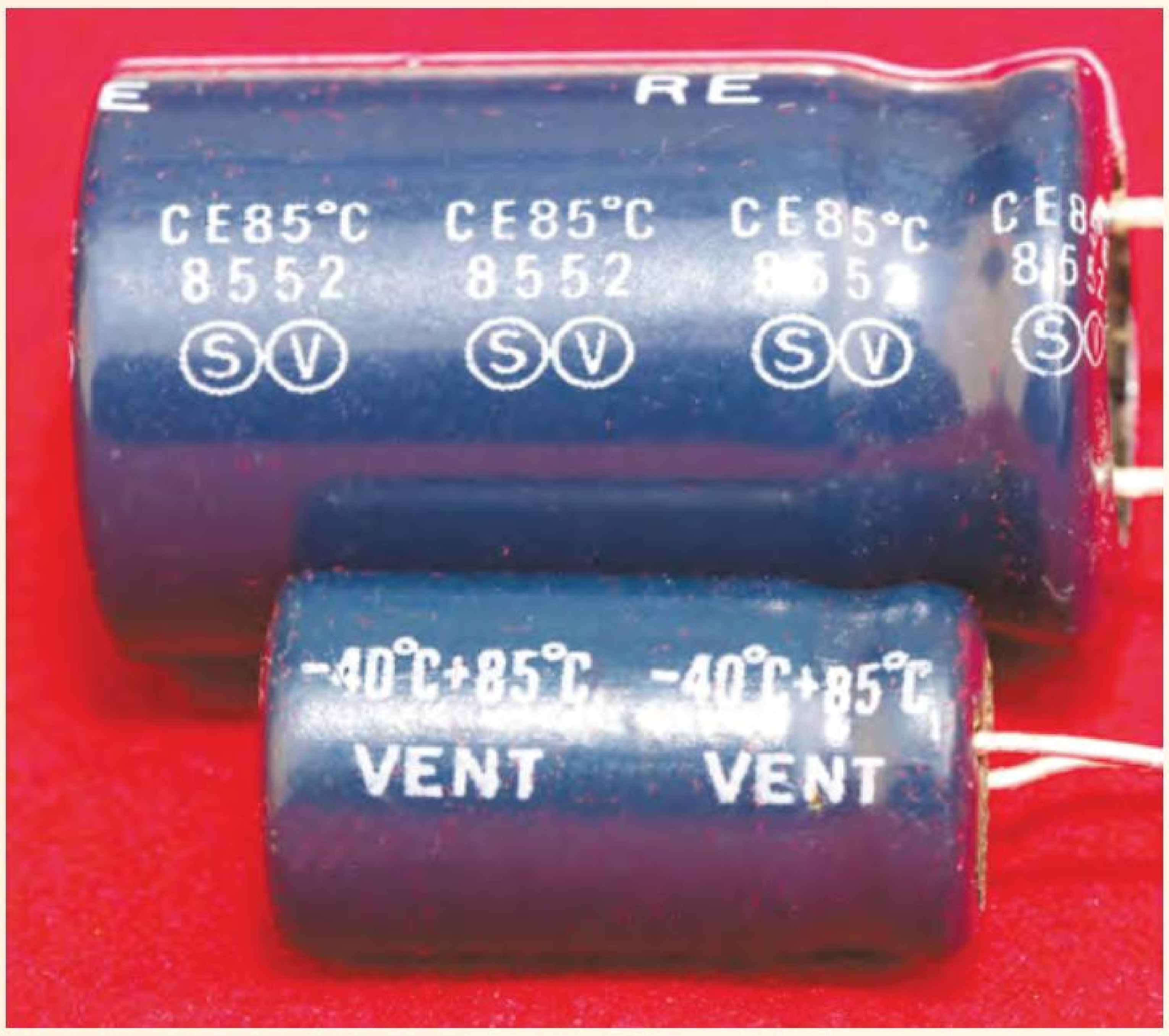


Fig.1. Some electrolytic capacitors are marked with maximum, or minimum and maximum operating temperatures. The operating range is usually very wide, as in these examples

Tolerance letter

Higher wattage resistors, capacitors, and possibly some other components such as inductors, are often marked with what may seem to be a meaningless letter. In some instances, it might actually be of no significance, but it is usually a code letter that indicates the tolerance rating of the component's value. For example, if a 100 nanofarad capacitor is marked with a letter 'K', its tolerance rating is plus and minus 10 percent, and its actual value is somewhere in the range 90 to 110 nanofarads. Code letters are not always used, and the tolerance value is often just written on the component.

The tolerance rating of a component is not always of great importance, but unless you know what you are doing it is advisable to assume that it is and always use a component of adequate quality in this respect. It is all right to use a component that has a tighter tolerance rating than the one called for in a components list, but one having a larger tolerance figure should not be used. Table 1 lists the common tolerance code letters and the values that they represent.

Table 1: Tolerance codes

Code letter	Tolerance
F	± 1%
G	± 2%
J	± 5%
K	± 10%
M	± 20%

Mistaken identity?

Semiconductors such as transistors often have markings other than the type number. Some of these can look a bit like type numbers, but it is usually quite easy to sort out the genuine type number from batch numbers, date codes, or whatever. The more usual problem with semiconductor markings is that the type numbers marked on the supplied devices are not quite as expected. This could be due to an error and the wrong components being supplied, but in most cases it is simply due to the fact that many semiconductors are sold under two or more slightly different type numbers.

Semiconductor type numbers generally break down into three sections, but small semiconductors such as transistors and diodes have a slightly different system to the one generally used for integrated circuits. Taking small semiconductors first, the middle section of the type number is the most important one because it is the serial number. This usually has three or four digits, and if it is incorrect, you certainly have the wrong component.

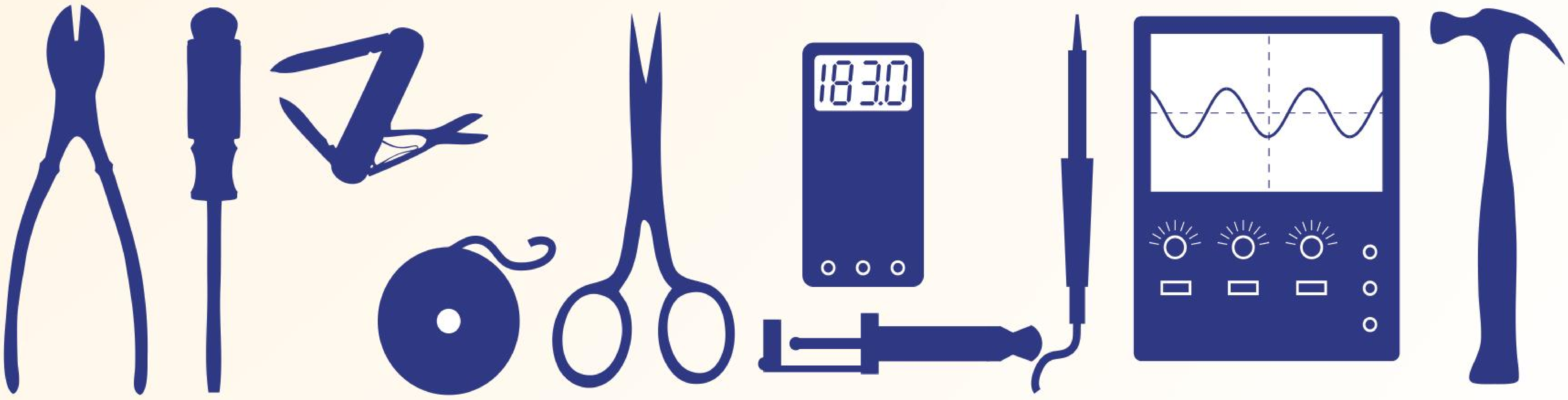
The initial part of the type number for European Pro Electron devices gives some basic information about the type of device. For example, the first letter is 'A' for a germanium component or 'B' for a silicon device. The second letter indicates the type of component, such as 'A' for a signal diode and 'C' for a low power audio transistor.

Semiconductors that have American JEDEC (Joint Electron Devices Engineering Council) type numbers have a prefix that consists of a number followed by the letter 'N'. The number is '1' for diodes and rectifiers, '2' for normal transistors, and '3' or more for special devices such a dual gate MOSFETs. The number is simply one less than the number of leads that the device has. A 1N914 therefore has two leadout wires, and it is actually a small diode. However, the exact type of component is not conveyed by JEDEC type numbers, which are less helpful than the Pro Electron ones. They are really just stating the obvious.

JIS (Japanese Industrial Standards) type numbers again start with a number that is one less than the component's number of leadout wires. This is followed by two letters that identify the general type of device, rather like the European system, but the coding is different. As a couple of examples, SA indicates a high frequency NPN transistor, and SC is the code for an audio PNP type. For normal types of transistor the first two digits are always '2S', and perhaps a little unhelpfully, these two digits are often omitted from the type numbers marked on the devices (Fig.2). With small semiconductors it is clearly important that the prefix is correct, and it is not just the serial number that is of importance. The BC161, BD161, 2N161 and 2SB161 are different devices.

Most small semiconductors have type numbers that conform to one of the three standards, but there are inevitably some exceptions. The only ones you are most likely to encounter are those produced by Texas Instruments, or other manufacturers' versions of these devices. These components have prefixes such as 'TIP' and 'TIS'. There are others though (Fig.3).

The third section of the type number is usually absent in the case of small semiconductors, but there are exceptions. Some European transistors are available in low, medium and high gain versions, which respectively have 'A', 'B', and 'C'



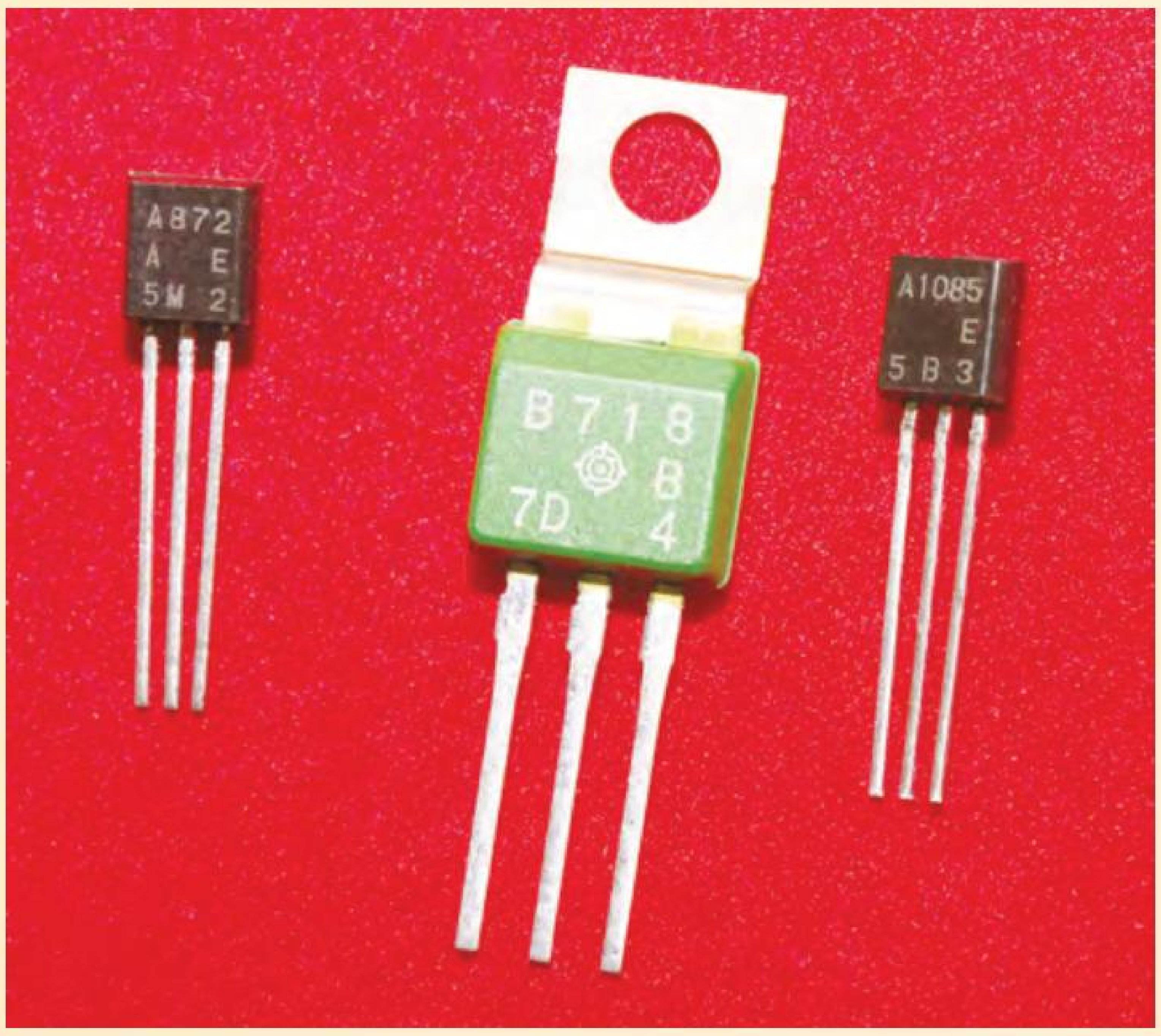


Fig.2. These are 2SA872, 2SB718, and 2SA1085 transistors. It is normal with JIS type numbers for the '2S' part to be omitted on the actual components

suffix letters. Versions which lack a suffix are also available, and these can be high, medium, or low gain devices. It is important to use the specified type if a components list includes one of these suffix letters, but they are otherwise of no importance.

In the past, a suffix letter was sometimes used to indicate the leadout configuration of a transistor. This method seems to have fallen from favour though, and these days each leadout configuration would instead be given a different serial number. If an old design should call for a transistor having a suffix such as 'L' or 'K', it is important to obtain the right type or to alter the method of connection to suit the different leadout configuration.

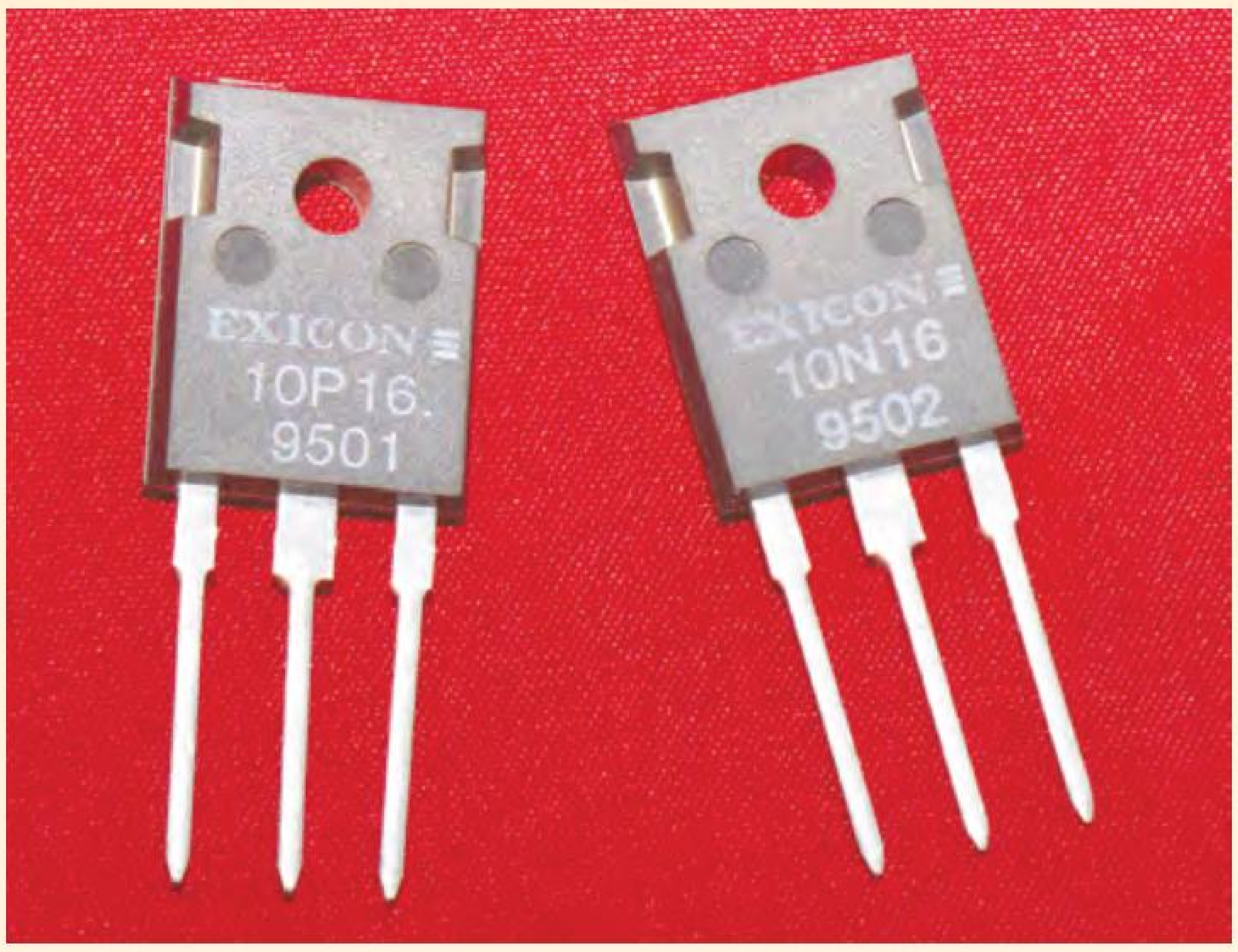


Fig.3. Not all transistors and diodes have JIS, JEDEC, or Pro Electron type numbers. These are EC-10P16 and EC-10N16 complementary power MOSFETs

On the make

A few integrated circuits have European Pro Electron type numbers, but the normal method these days is for the prefix to indicate the maker, with the middle section carrying the serial number, and the suffix indicating the type of encapsulation. Since it does not matter whether a component is made by Motorola, RCA, or Texas Instruments, or any other company, the prefix is not of any importance. A CA1458 from RCA is the same device as the MC1458 from Motorola. It would make life a little easier for users if exactly the same type number was used by all manufacturers of an integrated circuit, but it is understandable if each manufacturer decides to use their own prefix.

Having components produced by more than one manufacturer is known as 'second sourcing'. It may seem strange for a company to license rivals to produce components that will be sold in direct competition to their own versions. However, equipment manufacturers do not like being tied to a single source of supply. Having alternative sources introduces competition that helps to hold down prices, and reduces problems if the originator of the device suddenly decides to 'pull the plug' on production. With two or more sources of supply a component is much more saleable.

The serial number of integrated circuits sometimes contains one or more letters, and in the case of voltage regulators a single letter indicates the current rating of the component. Table 2 shows the common code letters and the current ratings that they represent. A 78M12 is therefore a +12 volt regulator that can handle currents of up to 0.5 amps.

Table 2: Regulator current codes

Letter	Current rating
L	0.1A (100mA)
M	0.5A (500mA)
None	1A
S	2A

The original 74 series of TTL integrated circuits has type numbers that conform to the normal three-section convention, with the obvious proviso that the serial numbers all start with '74'. Numerous improved versions of the original devices have been produced over the years, but most of these are now obsolete. Some are still in use today though, and these have two or three letters added after the '74' part of the type number in order to distinguish them from the standard devices (Fig.4). For example, 'LS' is used for low-power schottky devices, and 'HCT' is used for high-speed CMOS devices that operate at standard TTL logic levels. The 74LS02 is therefore the low-power schottky version of the standard 7402 chip.

Compatibility between the various 74 series logic families is not particularly good, and they even have different supply voltage ranges. Unless you know what you are doing it is not advisable to use a device from the wrong 74 family. The chances of it working properly are not good, and it might even be damaged by an inappropriate supply voltage.

Case styles

Integrated circuits are usually available with various types of encapsulation. Many of the encapsulations and pin types of the past have now disappeared, but various surface-mount types have been added. Accordingly, many integrated circuits are available with a standard DIL (dual in-line) encapsulation of some kind, plus various surface-mount options. The suffix of the type number is used to

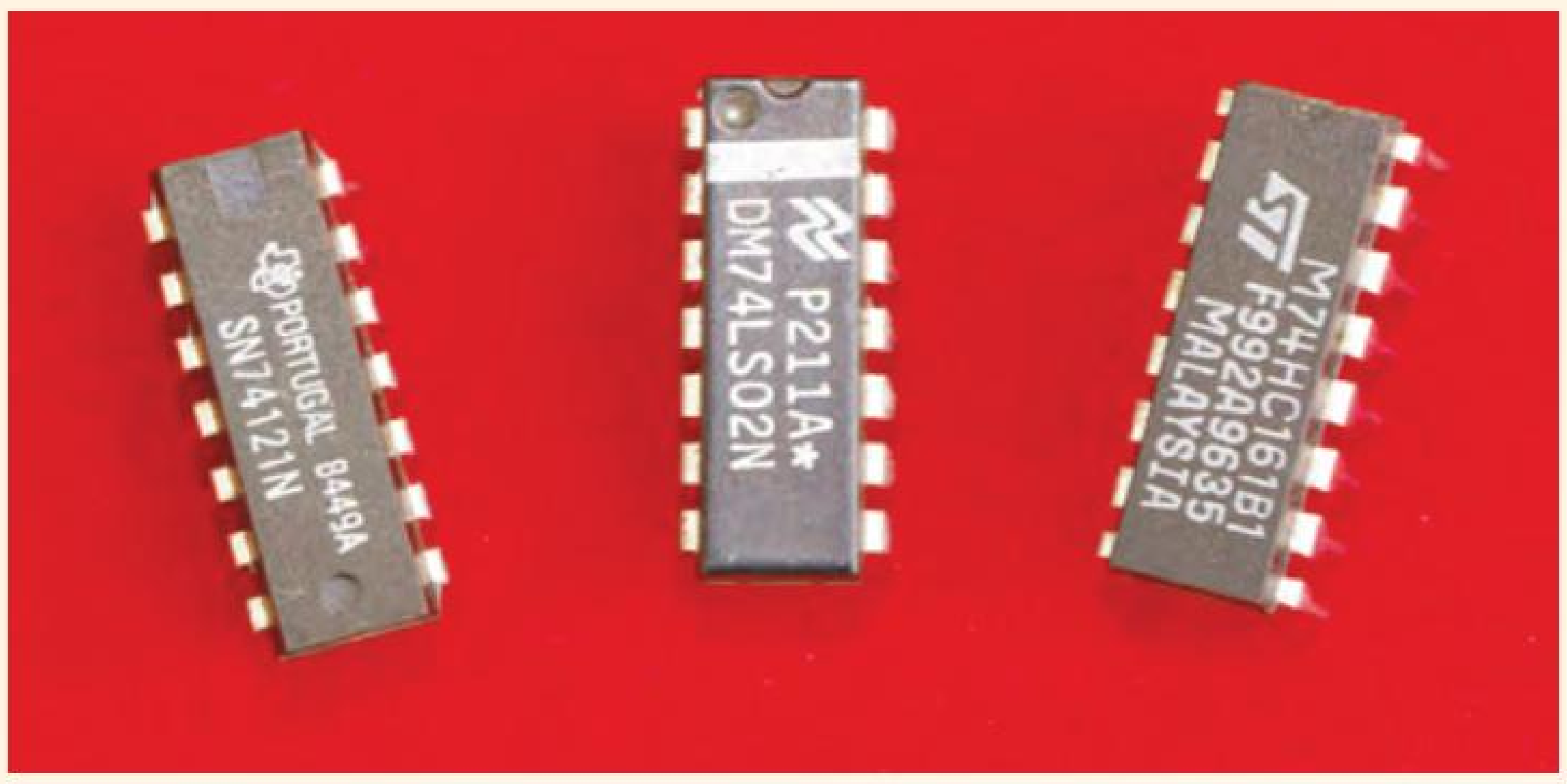


Fig.4. From left to right, these are a standard 74 series TTL device, a low-power schottky type, and a high-speed CMOS device. Compatibility between the various 74 TTL logic families is not very good, and it is advisable to only use the specified type

indicate the type of encapsulation of the device, and it might also give other information, such as whether a device is of consumer or military grade.

Clearly the suffix of an integrated circuit is something that cannot be ignored, and obtaining a device that has the wrong suffix will provide you with the right semiconductor chip, but in an encapsulation that is physically incompatible with the project's printed circuit board. Unfortunately, matters are complicated by a lack of proper standardisation for integrated circuit suffixes. Some suffixes are used by more than one manufacturer, but most seem to use their own system.

The MC1458CP and CA1458E have different suffixes ('CP' and 'E'). In the case of the MC1458CP the 'C' indicates that it is a standard DIL device, and the P indicates that it has a plastic casing. The 'E' in the CA1458E type number means the same thing, and the two devices are direct equivalents. In practice, this means that you have to make sure that the package type of the device you intend to buy matches the one specified in the components list. Provided these are the same it will not matter if the two type numbers have different suffixes.

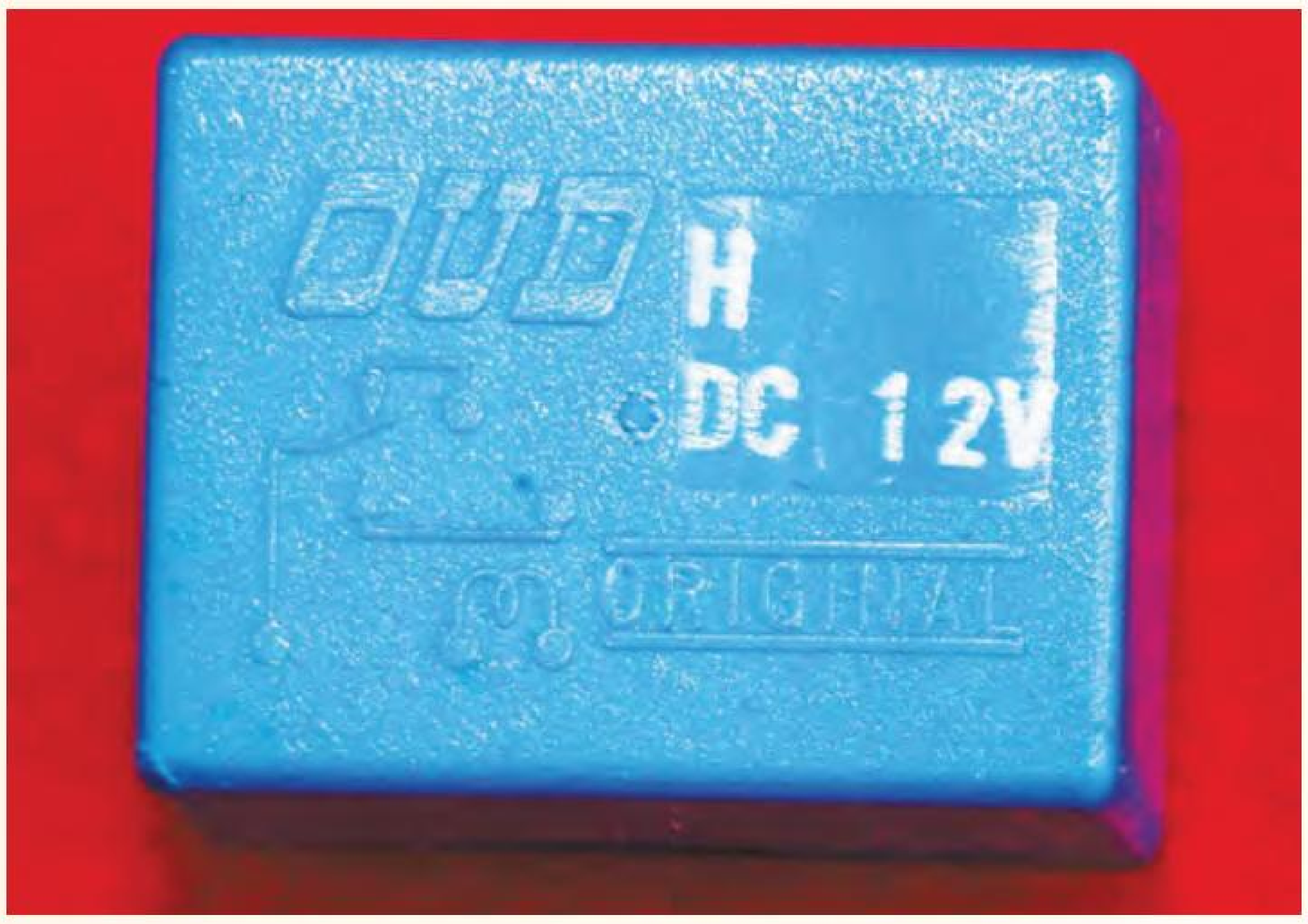


Fig.5. It is a bit difficult to see, but this relay has a pin connection diagram moulded into the top of the case in the bottom left-hand section. This can be useful if a relay has to be hard-wired to a circuit board

Over the years, *EPE* has often given the advice that you should make sure that all the components for a project are still available before actually buying any of them. Disappearing integrated circuits are a common source of buying troubles, and these days the problem can be due to the required DIL version being discontinued, with one or more surface-mount versions being left in production. There is a potential solution in the form of adapters that effectively convert surface-mount chips into DIL types. However, bear in mind that there is no guarantee that an adapted device will be a pin for pin equivalent to the DIL version, or even that it will have the same number of pins.

Relays

Relays are usually marked with the coil resistance and its nominal operating voltage, plus the manufacturer's logo and the usual extraneous letters and numbers. Some also carry a simple graphic that shows the function of each pin (Fig.5). This can be more than a little helpful if it is necessary to hard-wire the component to the rest of the circuit.

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32 digital input/output channels for your Raspberry Pi. Stack up to four IO Pi boards to give you 128 I/O channels.
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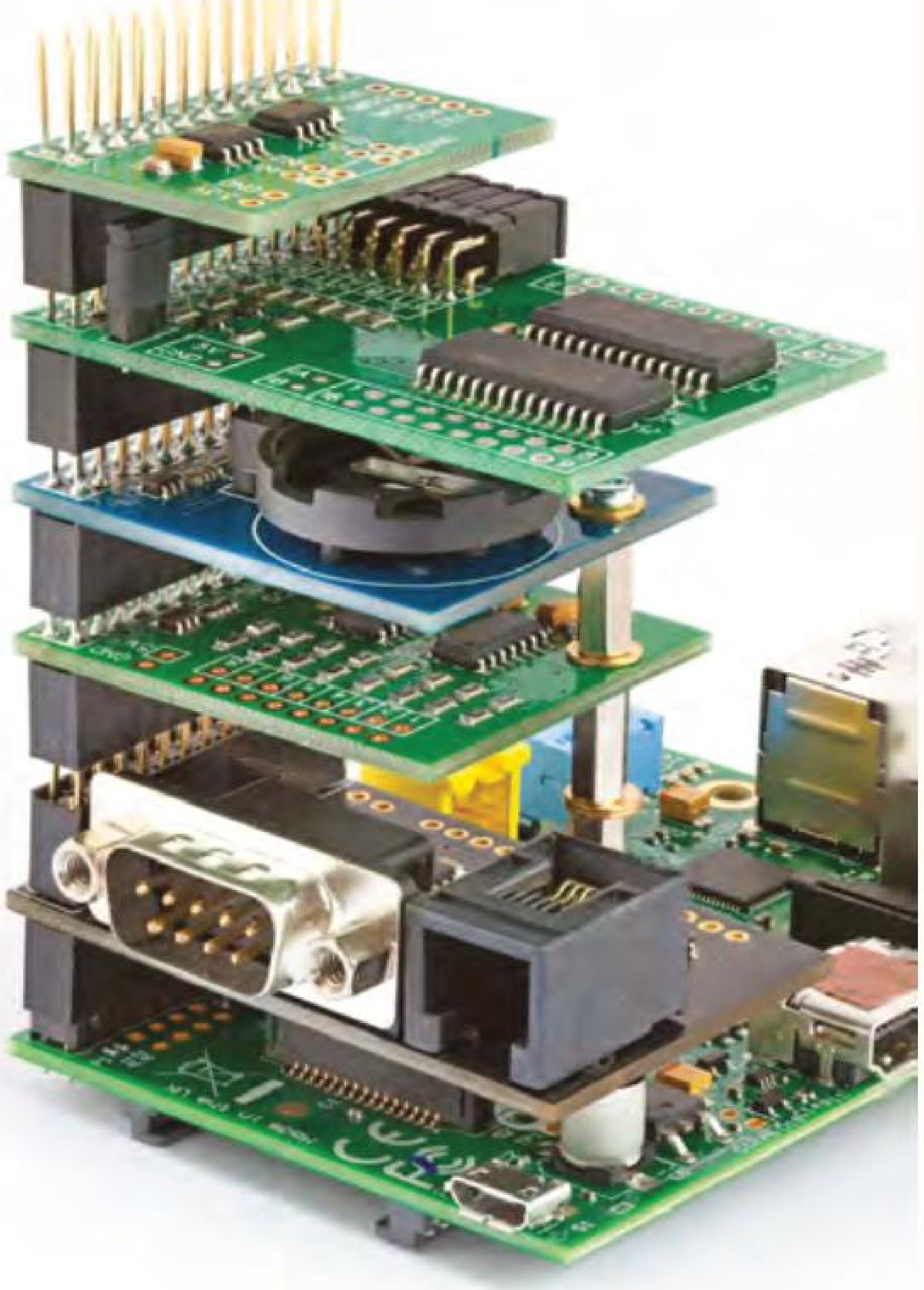


AUDIO OUT

By Jake Rothman

Eradicating wet electrolytic capacitors from audio circuits – Part 2

Distortion

Capacitor distortion is similar to that produced by magnetic tape and audio transformers; mainly second and third harmonic. It is rather innocuous, unlike crossover distortion in power amplifiers. Transformer coupling gives a distortion level at least an order of magnitude worse than wet electrolytic capacitor coupling. Solid-capacitor coupling is typically about halfway between the two.

A customer once asked me to take out the 'nasty tantalums' in a vintage Neve 1073 microphone pre-amp. Then he said it had 'lost some of its warm character'. They went back in, and the 'warmth' returned! My professional life seems to be caught between minimising distortion in hi-fi and monitoring systems, or maximising 'nice sounding' distortions in mic-preamps, processors and effects units.

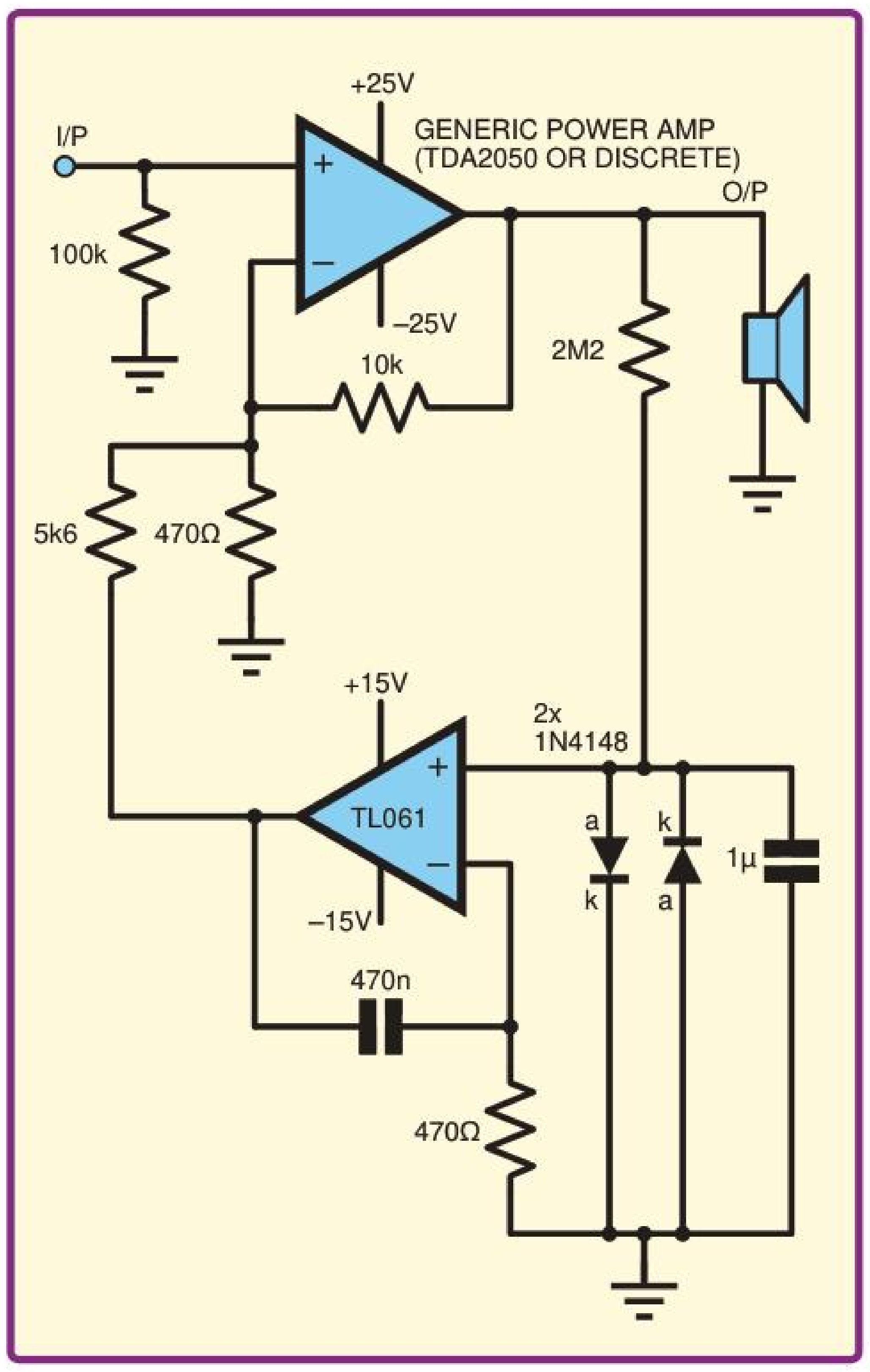


Fig.1. A servo can be used to eliminate the large electrolytic capacitors in power-amps. They will even eliminate the offset from preceding stages.

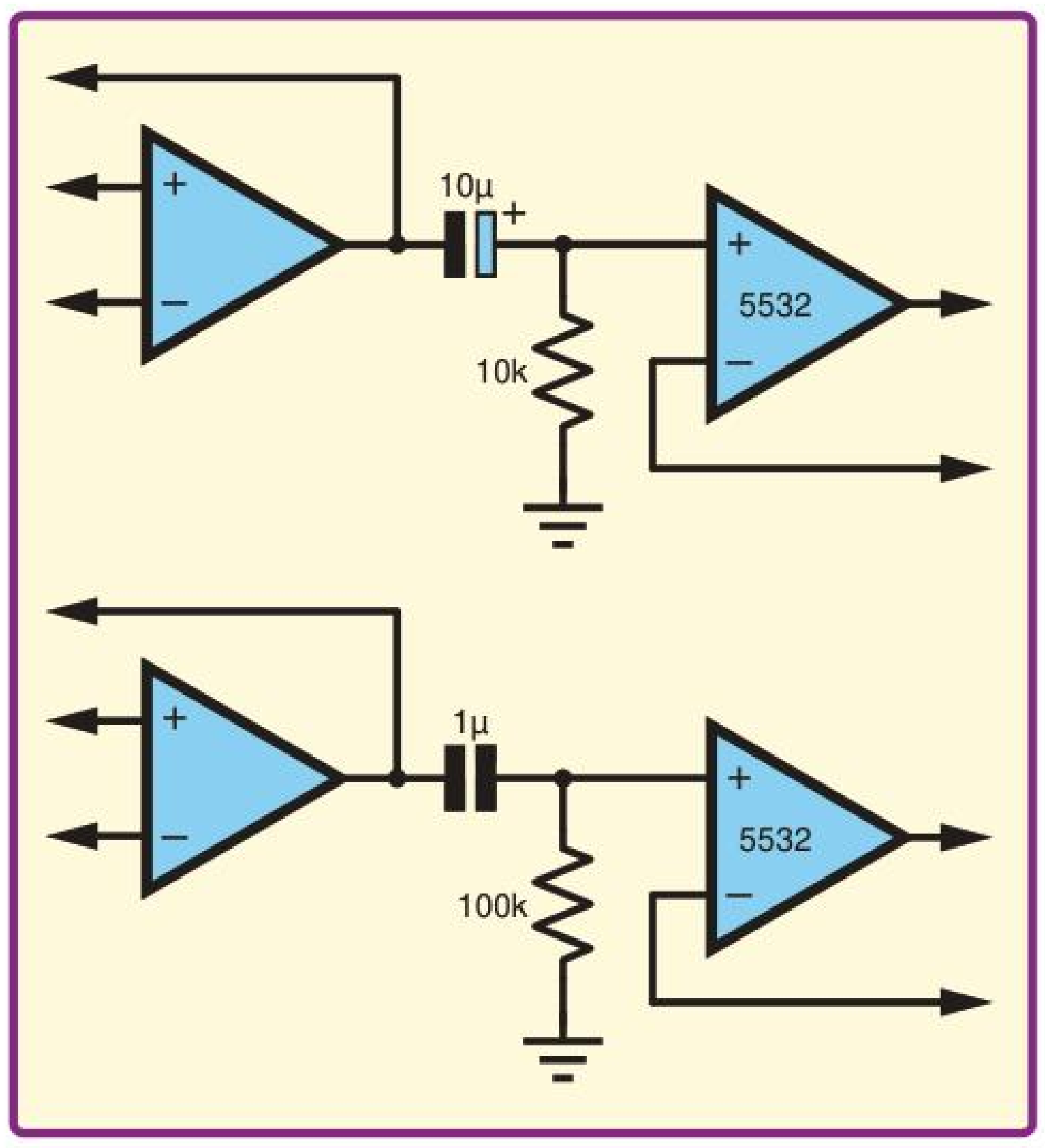


Fig.2. Increasing resistor values often allows capacitor values to be lowered, avoiding the need for electrolytic types. Watch out for increased offset voltages and noise.

Measuring total harmonic distortion is a blunt instrument in audio work, but it does show up non-linearities. Small amounts of harmonic distortion are often inaudible, but non-linearity leads to intermodulation distortion in music, where multiple instruments are combined at varying levels, which can sound unpleasant.

Modern music, with its high sub-bass content and layers of complex sounds can suffer 'pumping effects' from high capacitor distortion. With single sound sources and simple acoustic music, it is often un-noticeable and possibly enhancing. Most capacitor distortion is generally an inaudible second-order effect and can be safely ignored until all other sources of distortion have been dealt with.

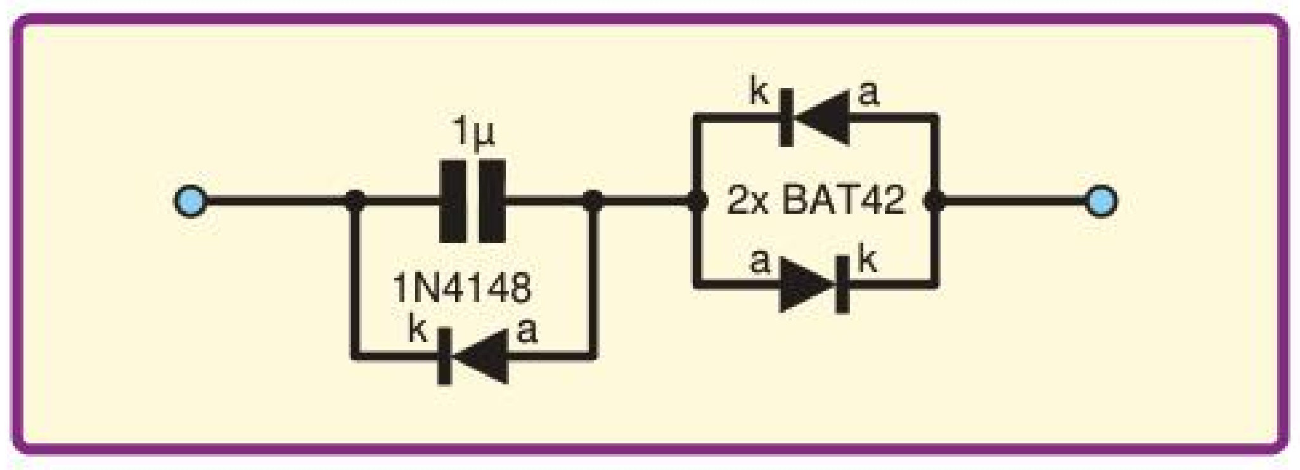


Fig.4. Extreme 'capacitor distortion' can be simulated by adding diodes to a capacitor.

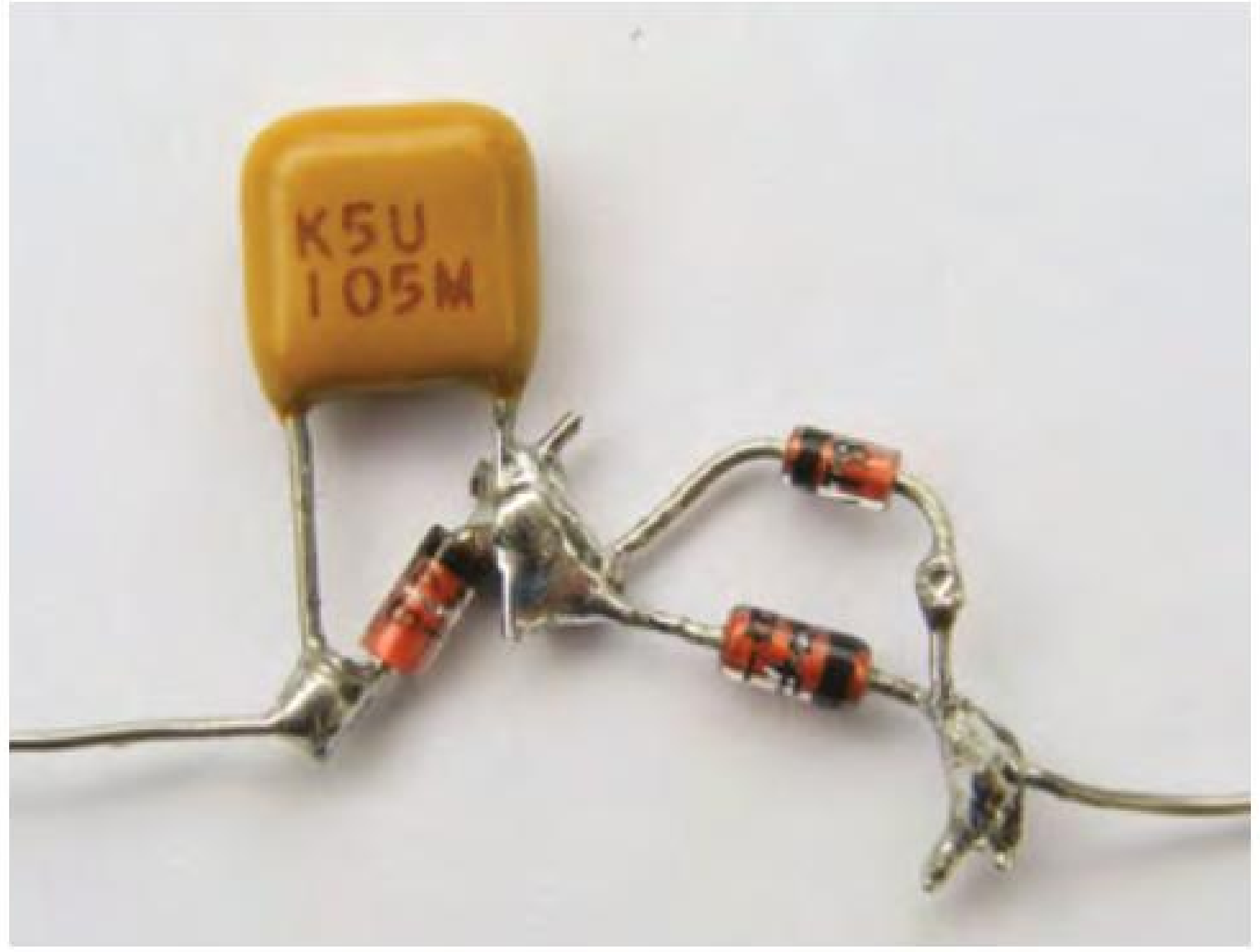


Fig.5. This 'bad cap' can be used to see the effect of distortion in various circuit locations.

Why use capacitors at all, DC coupling's all the rage isn't it?

I have thought about this with respect to my own designs, but decided 'DC coupling everything' – as popularised by the US hi-fi designers, was not an

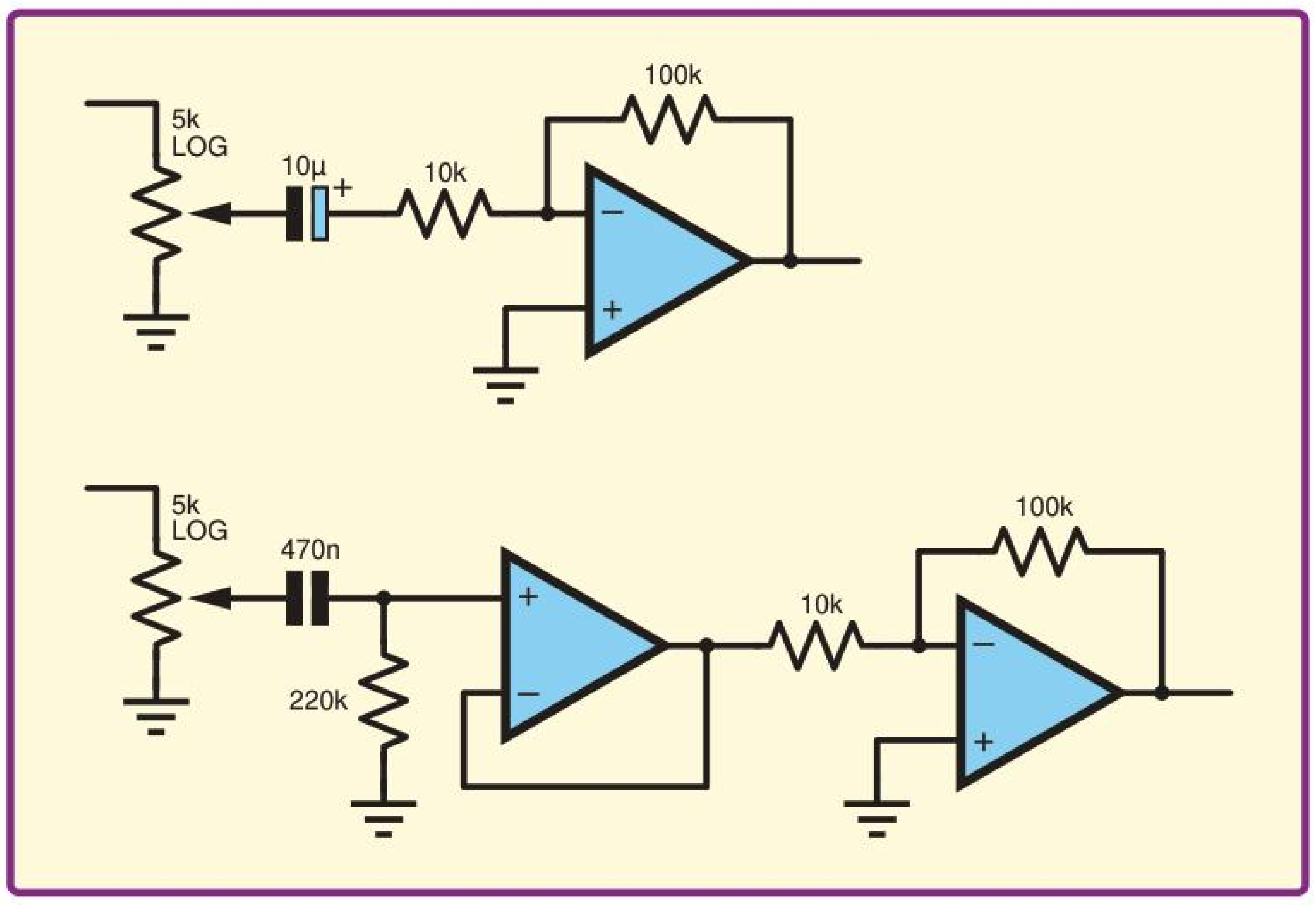


Fig.3. Adding a buffer amp can increase input impedance and eliminate a large electrolytic capacitor.

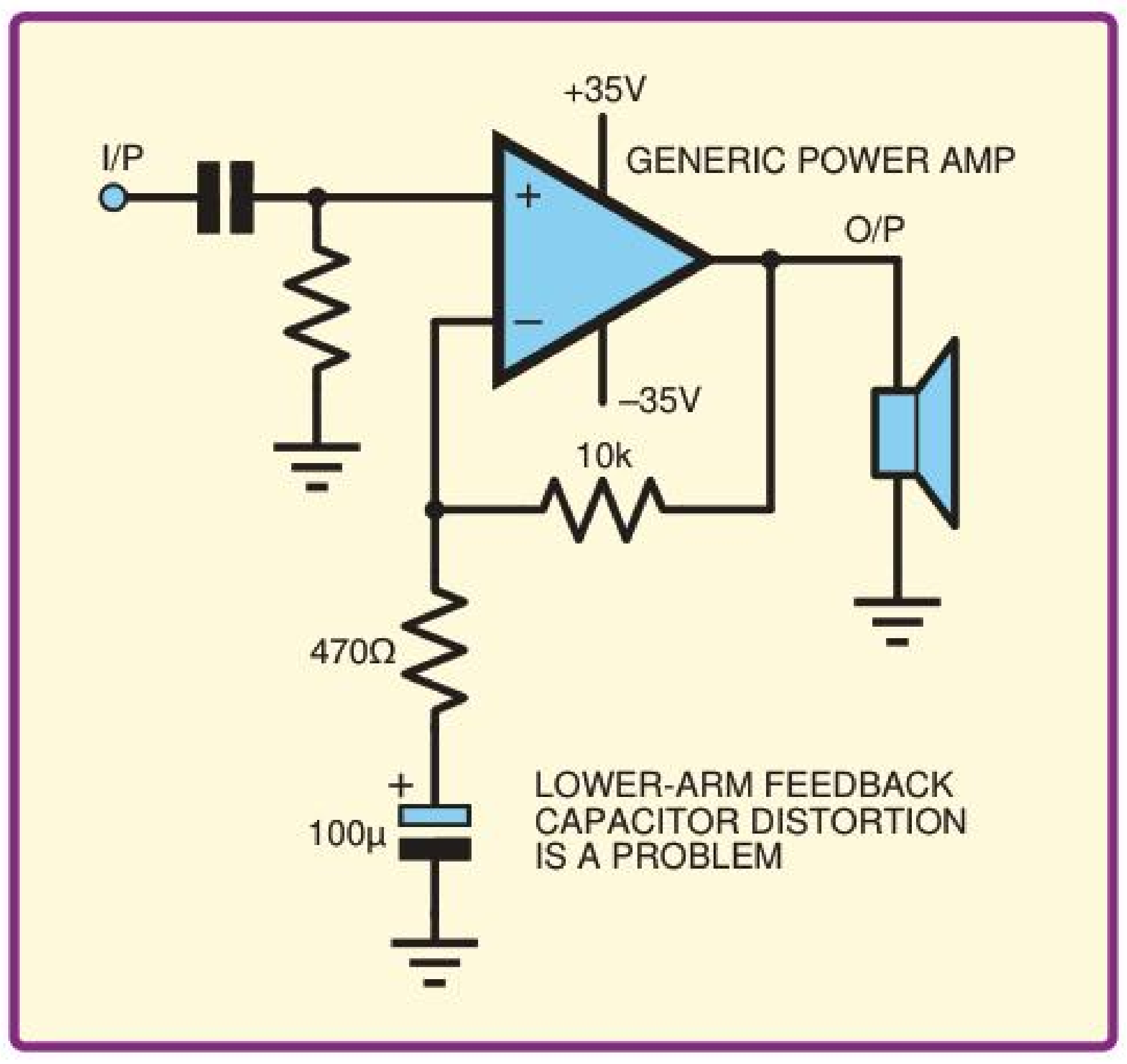

+35V
I/P
GENERIC POWER AMP
O/P
+
–
–35V
10k
470Ω
+
100µ
LOWER-ARM FEEDBACK CAPACITOR DISTORTION IS A PROBLEM

Fig.6. Capacitor distortion in the lower-arm of the feedback network in power amps is significant. A single tantalum bead here is not recommended.

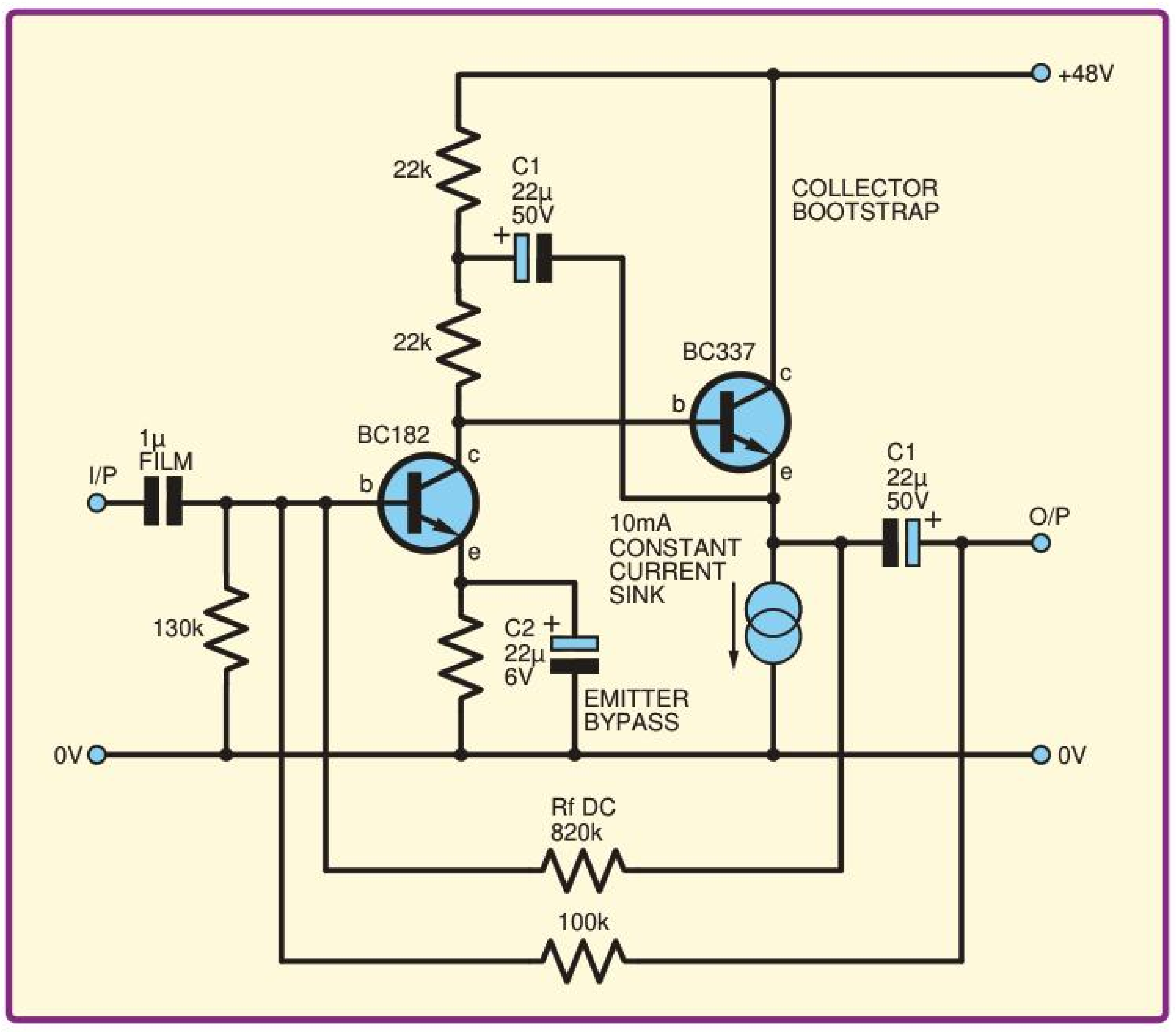

+48V
22k
C1 22µ 50V
COLLECTOR BOOTSTRAP
22k
BC337
b
c
e
BC182
c
b
e
1µ FILM
I/P
C1 22µ 50V
O/P
10mA CONSTANT CURRENT SINK
130k
C2 22µ 6V
EMITTER BYPASS
0V
0V
Rf DC 820k
100k

Fig.7. Pre-amp emitter bypass and collector-load bootstrap capacitor distortion is reduced by overall negative feedback. Tantalum types can be substituted here.

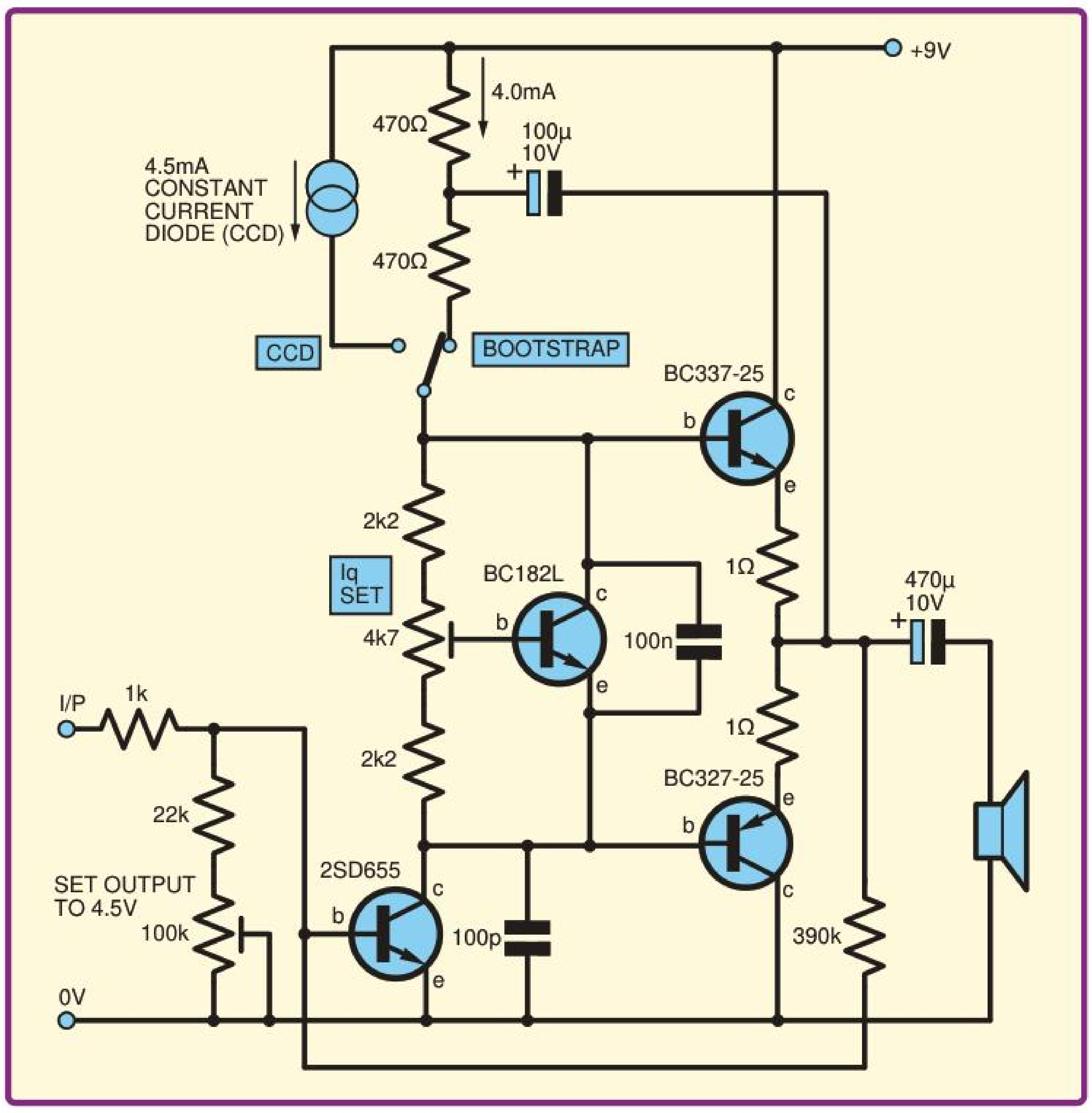

+9V
470Ω
4.0mA
100µ 10V
4.5mA CONSTANT CURRENT DIODE (CCD)
470Ω
CCD
BOOTSTRAP
BC337-25
b
c
e
2k2
Iq SET
BC182L
c
b
e
4k7
100n
1Ω
470µ 10V
1Ω
I/P
1k
2k2
BC327-25
b
e
c
22k
SET OUTPUT TO 4.5V
100k
2SD655
b
c
e
100p
390k
0V

Fig.8. In this small power amp, collector bootstrapping capacitors can be eliminated by replacing the three-component network with a constant-current source. This can be a single constant-current diode (CCD). Note this reduces the power output from 600mW to 420mW, but the crossover distortion is better.

option. There will always be switches and pots in analogue music gear, which generate noise with the slightest trace of DC. Plus, audio has no need to go down to DC, unless you want to recreate the earache of an aircraft landing.

It is worth remembering that DC 'servos' increase power consumption and complexity. However, if you want to experiment with servos, one I use is given in Fig.1. This eliminates the lower-arm feedback capacitor used in many power-amps. For DC-coupled audio, expensive low-bias current and offset op-amps are needed, which may have higher noise and distortion, since their main markets are not audio. Cost-effective audio op-amps, like the 5532, have poor DC specs, due to their high current bipolar input stages. Consequently, lots of coupling capacitors are mandatory. The low impedances used to minimise noise also means that capacitance values have to be high, and electrolytic types for values above 1µF have to be used.

Initial approach

The first line of attack in getting wet electrolytic capacitors out of designs should be to replace all the low values with film-type capacitors. 5mm-pitch polyester capacitors are available from Wima up to 3.3µF at prices similar to tantalum types. Increasing a few resistor values will often allow coupling capacitor values to be lowered, further eliminating electrolytic capacitors, as demonstrated in Fig.2. Remember, with modern components, adding an extra transistor or op-amp to

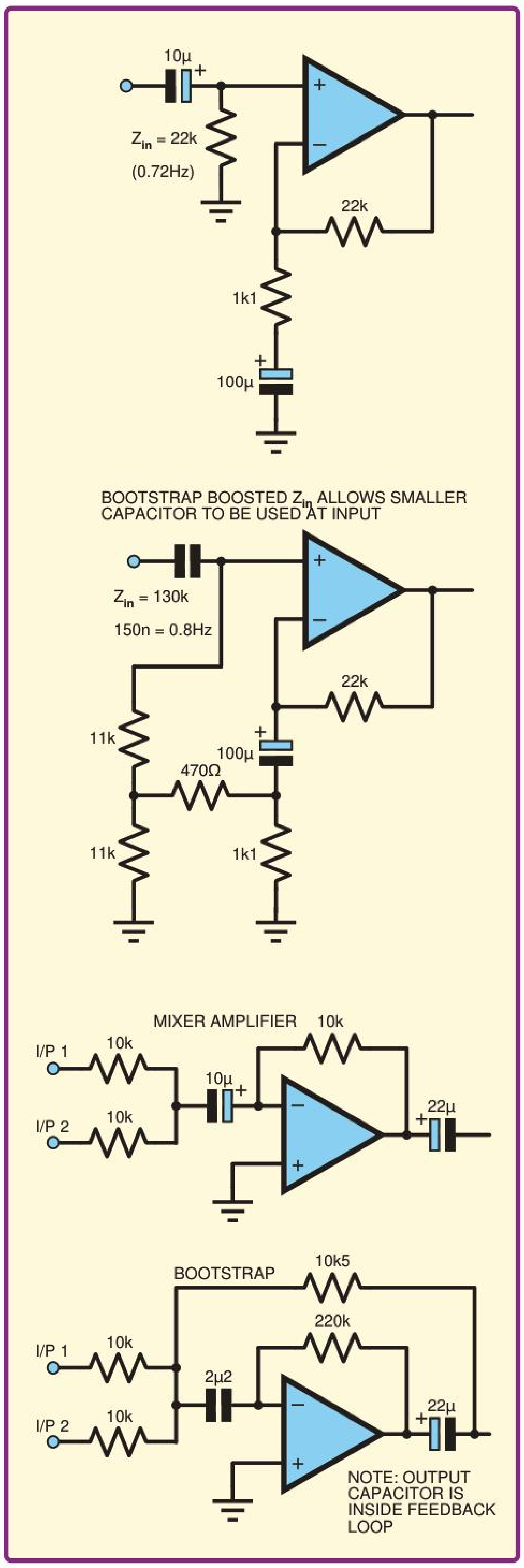

10µ
+
Z_{in} = 22k
(0.72Hz)
+
–
22k
1k1
100µ
BOOTSTRAP BOOSTED Z_{in} ALLOWS SMALLER CAPACITOR TO BE USED AT INPUT
Z_{in} = 130k
150n = 0.8Hz
+
–
22k
11k
100µ
470Ω
11k
1k1
MIXER AMPLIFIER
10k
I/P 1
10k
10µ
I/P 2
10k
22µ
–
+
BOOTSTRAP
10k5
220k
I/P 1
10k
2µ2
I/P 2
10k
22µ
–
+
NOTE: OUTPUT CAPACITOR IS INSIDE FEEDBACK LOOP

Fig.9. Bootstrapping can be used on inputs to increase input impedance without increasing offset voltage, allowing film capacitors to be used.

eliminate a wet electrolytic capacitor will improve overall circuit reliability (Fig.3).

'Extra-bad' capacitors

Some circuit locations are more critical than others. I have built 'extra-bad' capacitors consisting of a Y5V ceramic capacitor with added diodes – see Fig.4 and Fig.5. These 'capacitors' make distortion so bad it is visible on a 'scope. I can then assess the impact capacitor distortion may have in certain positions and check the effectiveness of any distortion reduction measures. For instance, any distortion in the lower-arm feedback capacitor in power amplifiers is especially noticeable. (Designer

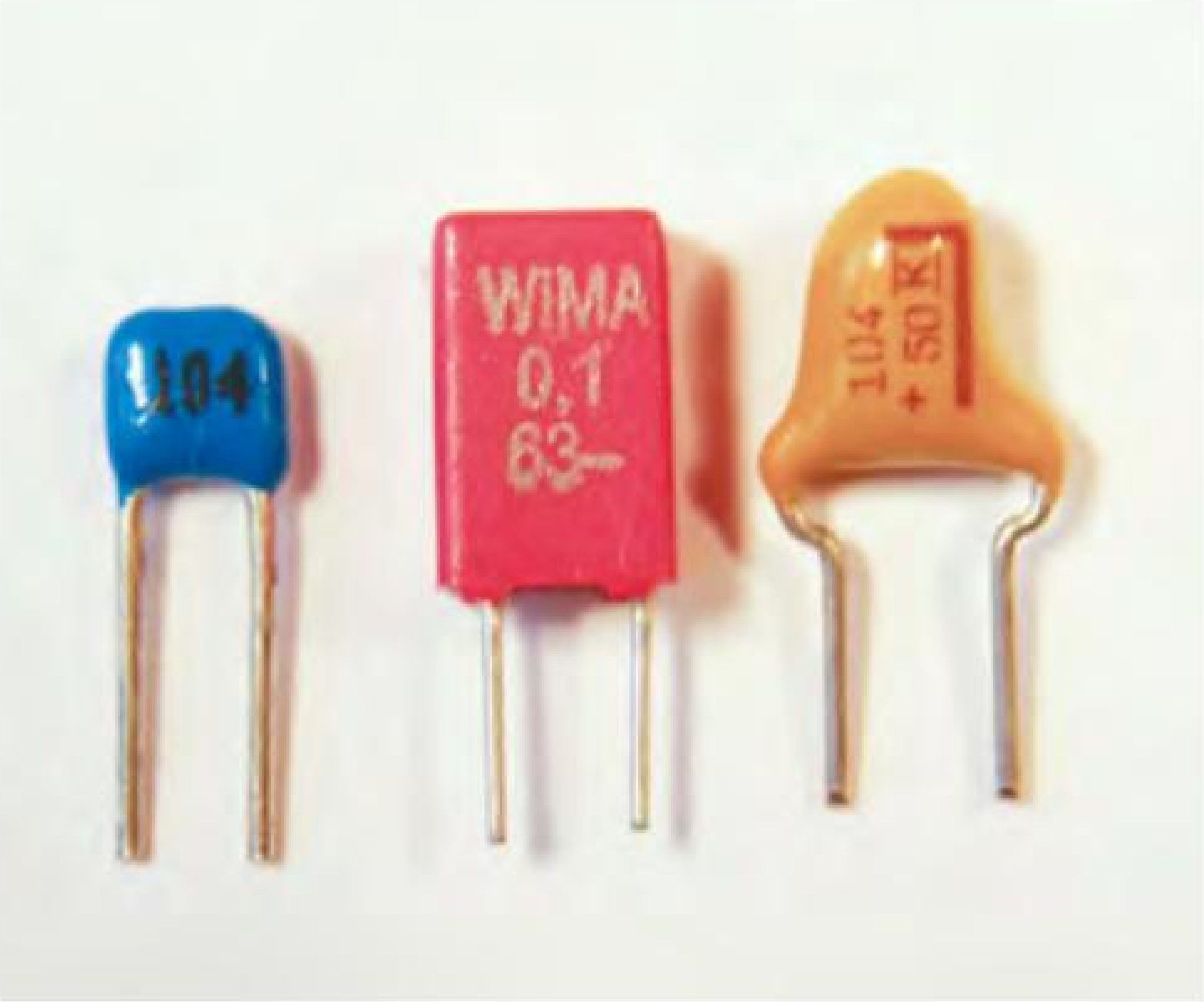


Fig.10. 100nF capacitors – left to right multilayer X7R ceramic, polyester film and tantalum bead. Obviously the film type should be used for through-hole construction.

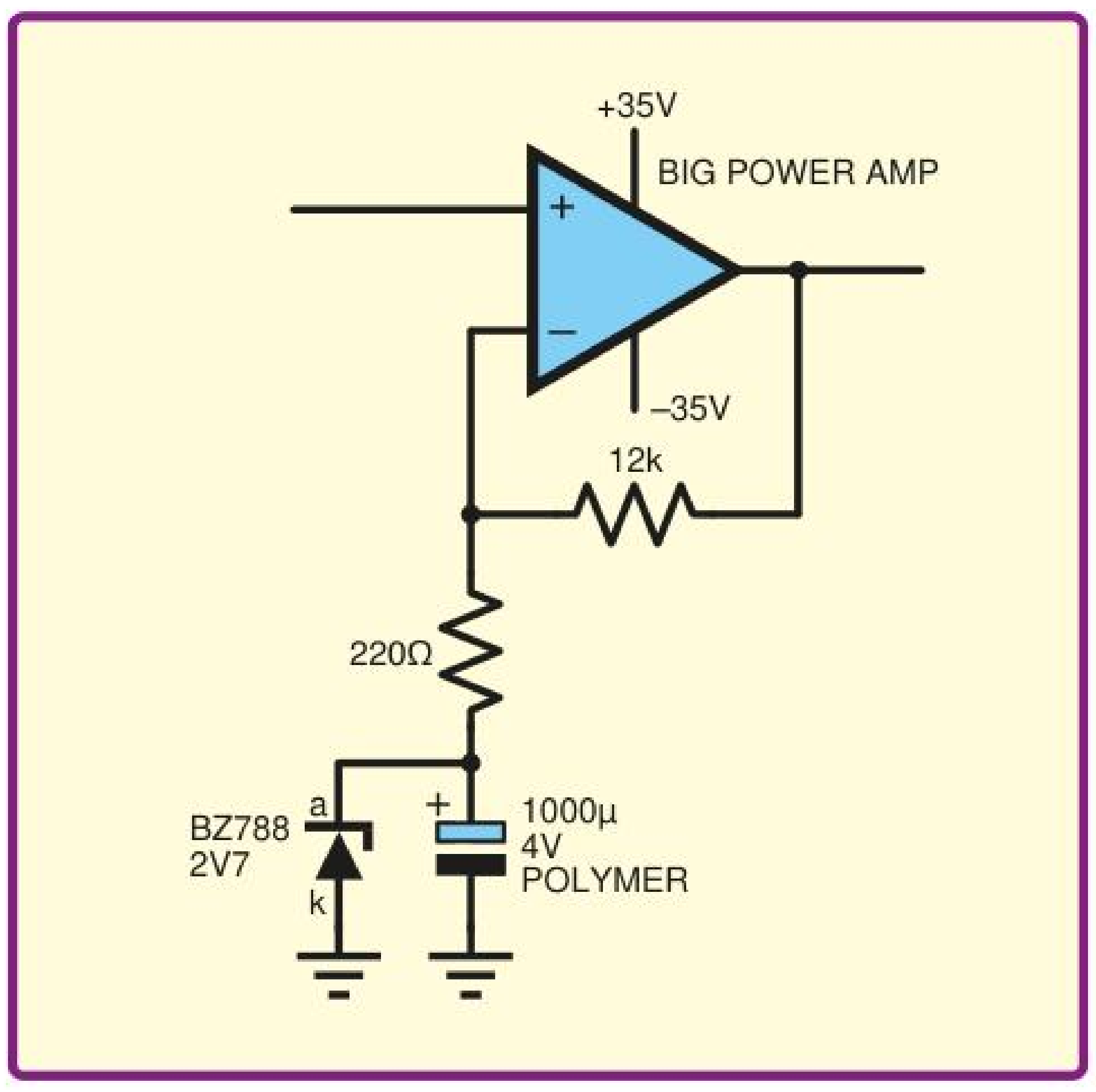


Fig.11. If a large value solid capacitor is required, a low voltage type can be used with diode protection in the event of faults.

Ed Cherry was fond of saying 'avoid tantalum beads in this area', as far back as 1983 – see Fig.6).

Other areas, such as emitter bypass and collector-load bootstrap capacitors are much less critical, overall negative feedback will linearise them, as shown in Fig.7. Collector bootstrap capacitors can be eliminated by replacing them with constant current diodes/circuits if the power supply voltage is high enough to lose a few volts – see Fig.8. Input capacitors are also sensitive; Fig.9 shows how bootstrapping can be used to avoid large values, allowing film types to be employed.

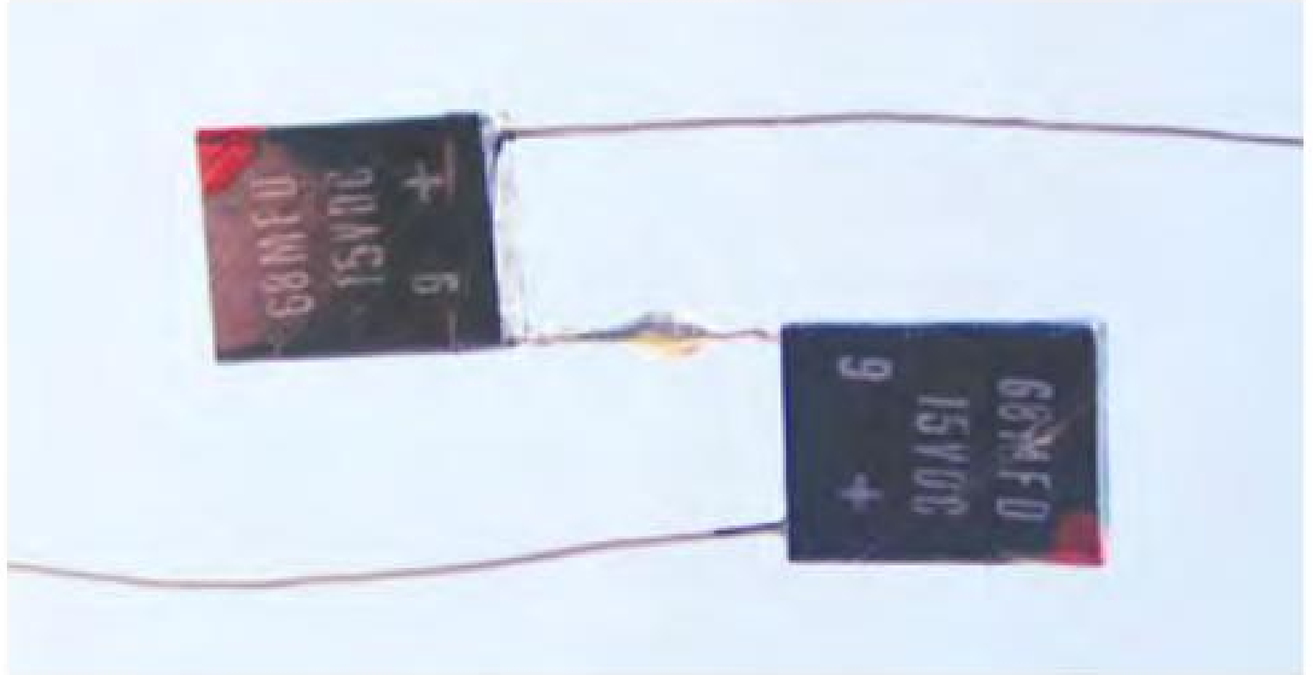


Fig.12. Connecting two tantalum capacitors in series back-to-back reduces distortion by almost six times.

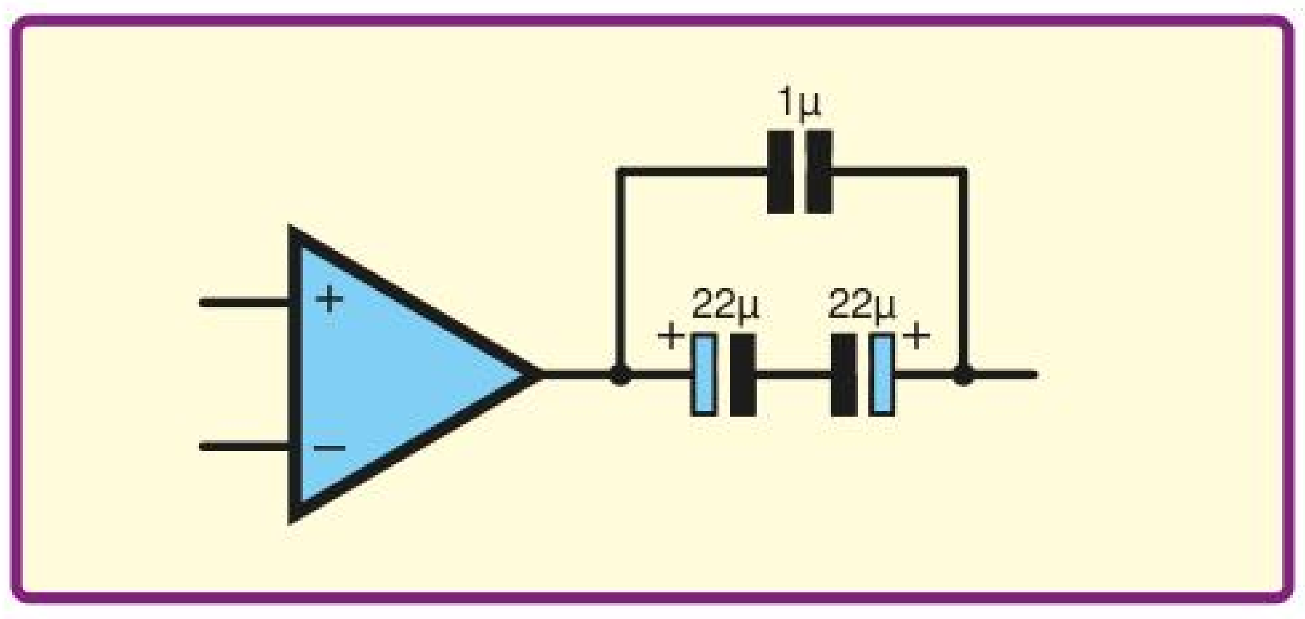


Fig.13. Back-to-back tantalum capacitors with a smaller plastic-film bypass capacitor reduces the distortion above the low frequency rise.

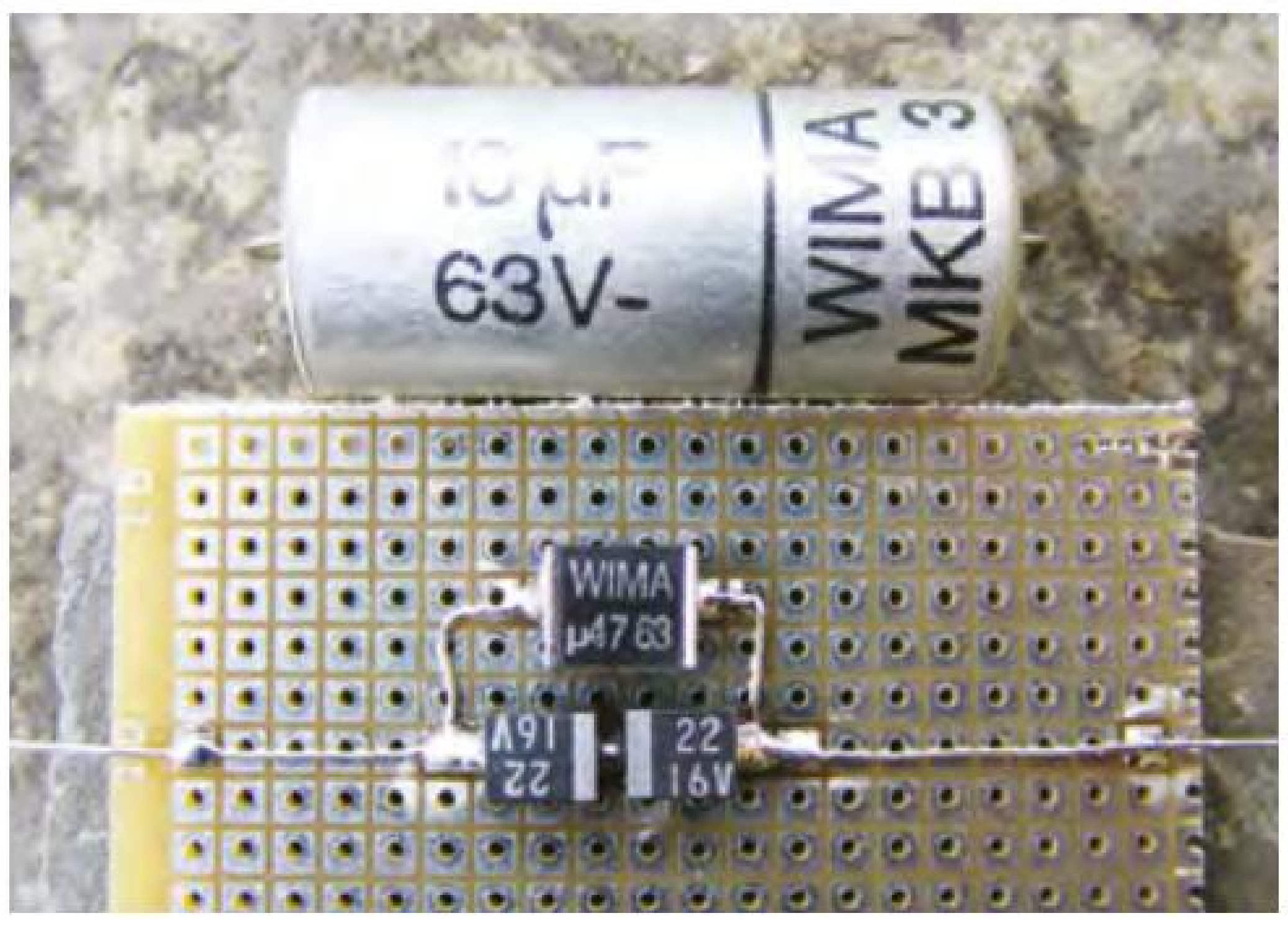


Fig.14. Note the difference in size between the composite tantalum capacitor and the equivalent film type (top).

I have seen leaded 100nF to 680nF tantalum capacitors, shown in Fig.10. What is the point in using them when film types are almost now the same size and cost? However, with surface mount components, tantalum capacitors are still much smaller. In such audio circuits, the choice is usually between multilayer ceramic capacitors (MLCCs) and tantalum types, and the MLCCs are much worse.

The rise in distortion as frequency is reduced, is also apparent with solid capacitors and it is worse than wet aluminium. It can't be dealt with by oversizing, because the maximum CV product values available in solid tantalums are limited from 22µF 50V to 330µF 6.3V, and they get very expensive at this level. Polymer capacitors can be a bit bigger at around 1000µF at 16V, although only recently have they been available at higher voltages. To enable high capacitance values to be used, a low voltage capacitor with diode protection can be used (Fig.11). In the future, graphene and nano-technology may greatly increase the capacitance available.

The back-to-back connection

The distortion rise at low frequencies with solid tantalum capacitors can be mitigated by putting two capacitors in series back-to-back – see Fig.12. The pair can then be bypassed by a film type to reduce the higher frequency distortion – see Fig.13. This technique was used in Jim Rowe's *USB instrument interface* in the December 2013 issue of *EPE*. The circuit board area of this technique is much less than the comparable film capacitor (Fig.14). A single capacitor will have much higher second harmonic distortion and will only give protection one way if a severe offset fault develops. If a very large value capacitor is needed to block small offset voltages/currents, say for potentiometer wipers, the back-to-back parallel connection can be used. (Fig.15 and Fig.16). Note that this configuration will only block 1.5V either way, so offers no circuit protection in the event of faults.

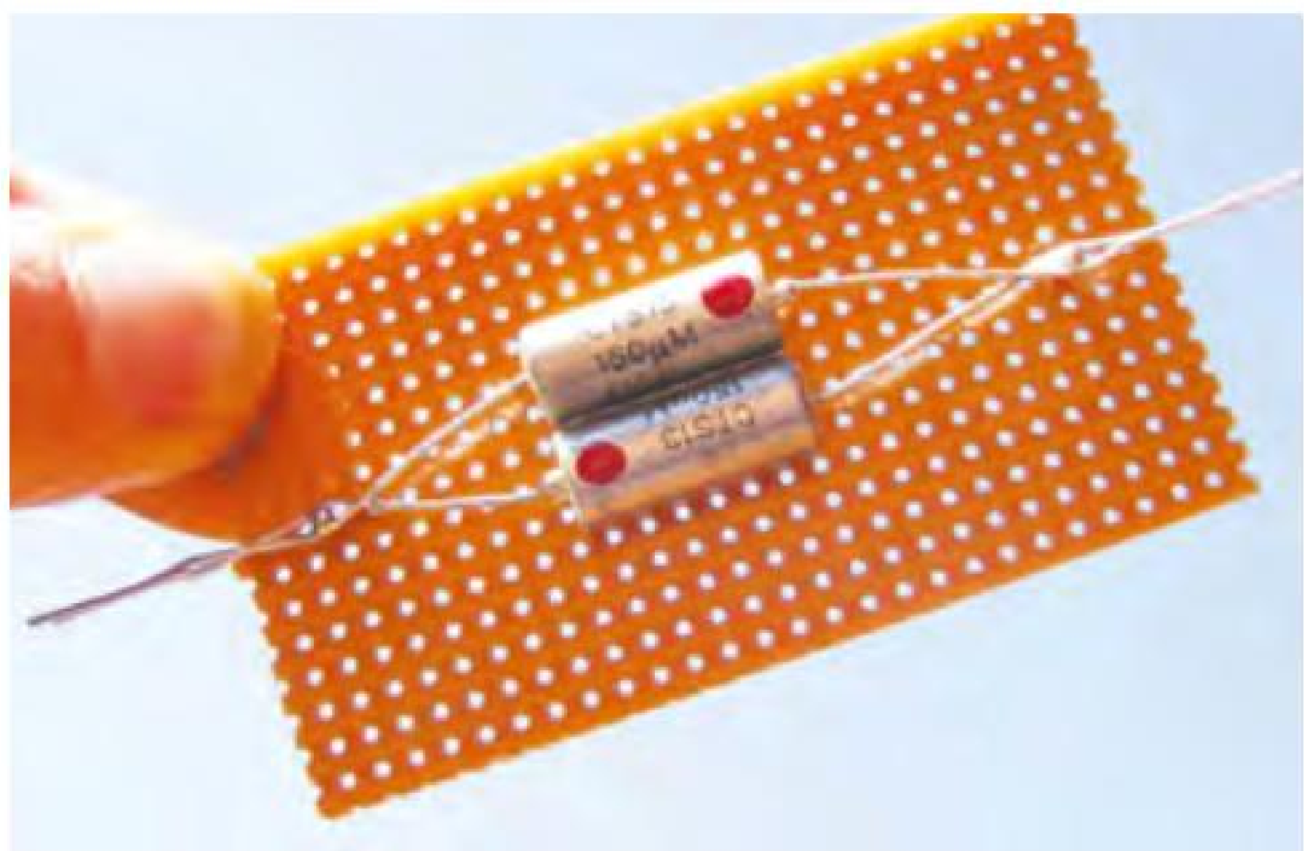


Fig.15. Parallel back-to-back connection of tantalum capacitors. This offers a major reduction in distortion, but will only block small voltages of up to 1V either way.

The distortion cancellation with bi-polar techniques depends on good matching between the capacitors and a reduction of up to 10× can be obtained. Sometimes the bi-polar connection can be obtained if input and output capacitors of interconnected stages are oriented correctly – see Fig.17.

Fig.18 shows a mixer channel strip that has been cooking in a hot rack

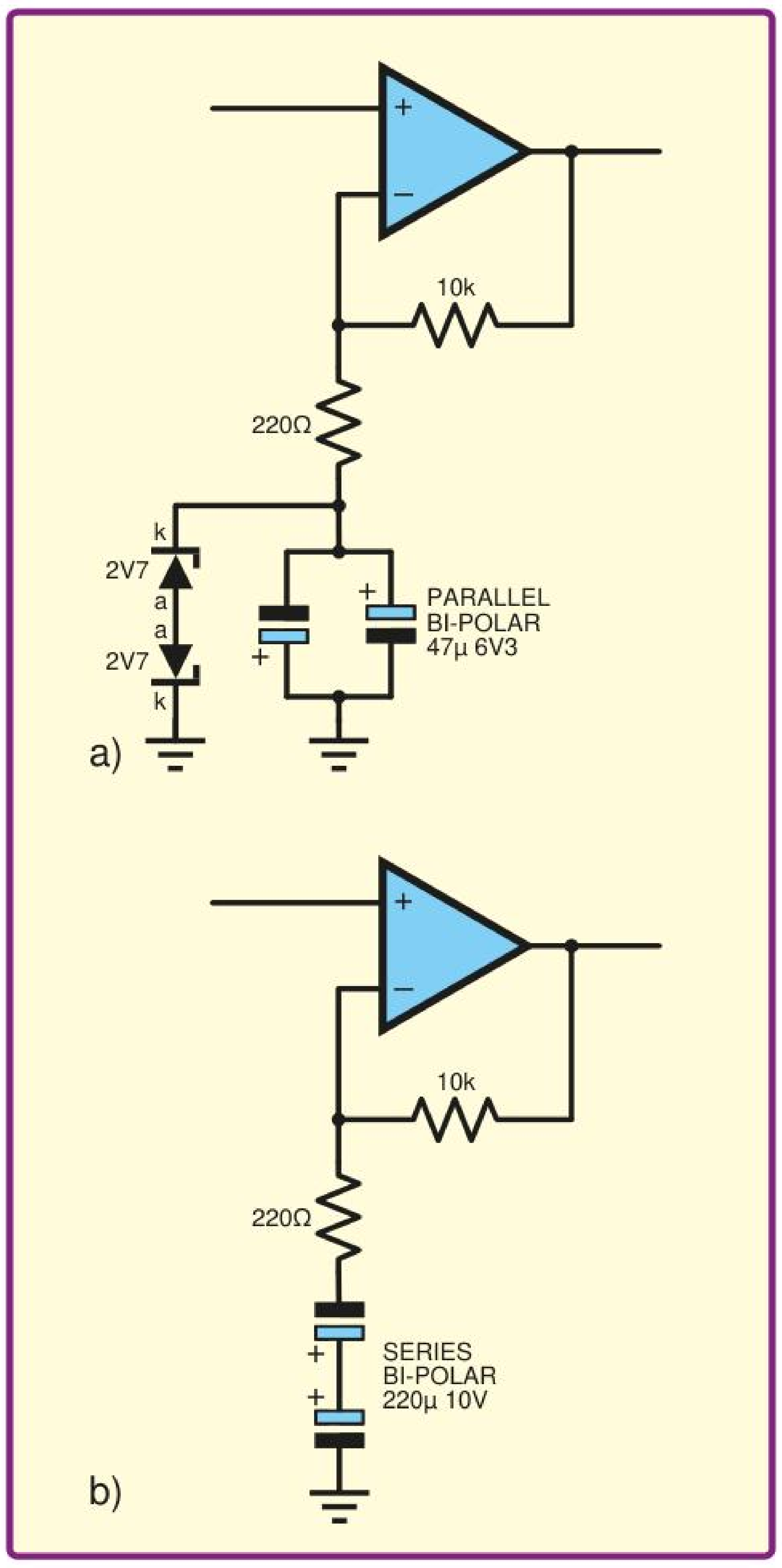


Fig.16. Bipolar solid capacitor configurations applied to lower-arm feedback capacitors.

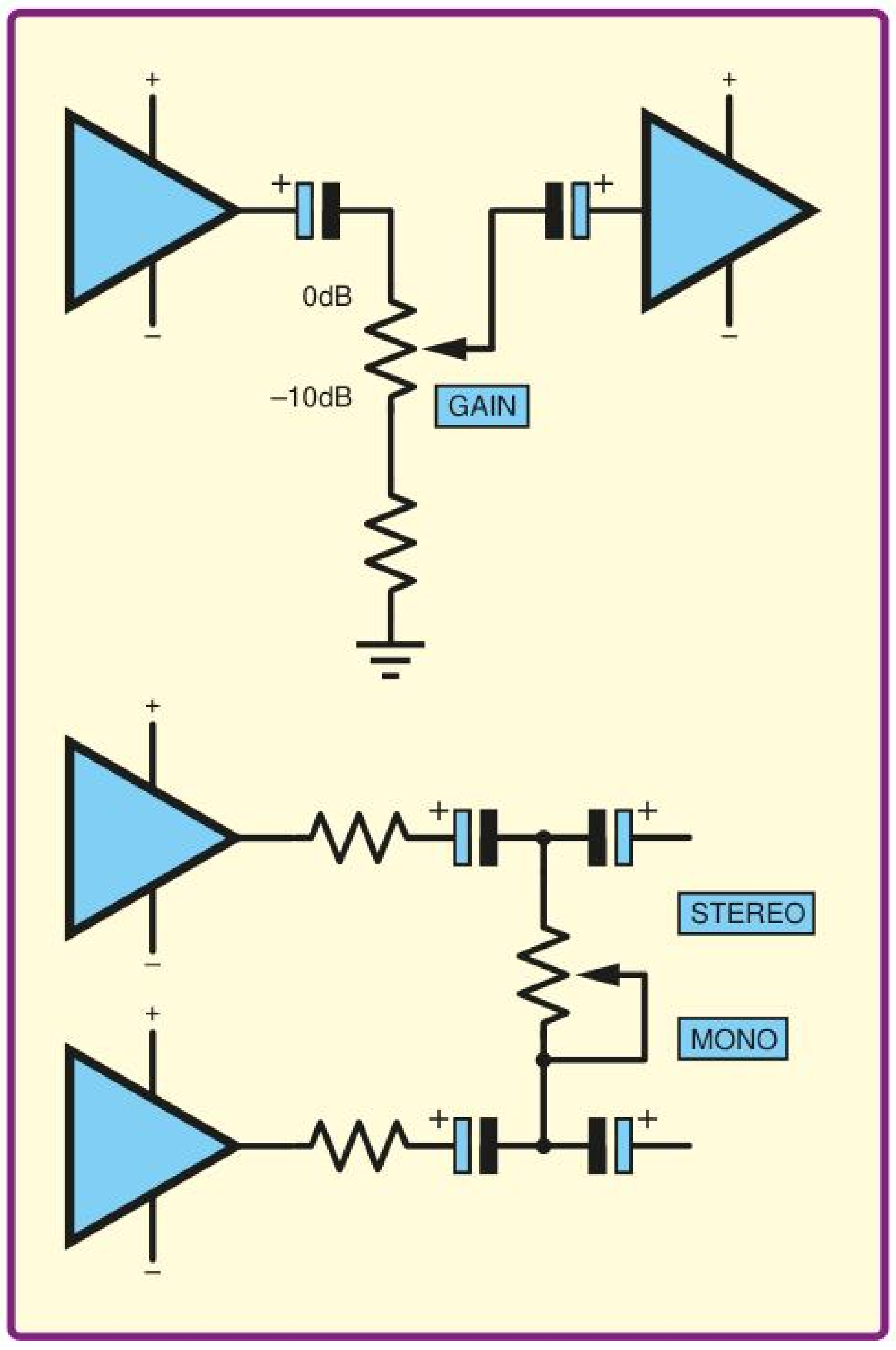


Fig.17. The bi-polar configuration can sometimes be obtained by correct orientation of capacitor polarity when interconnecting stages.

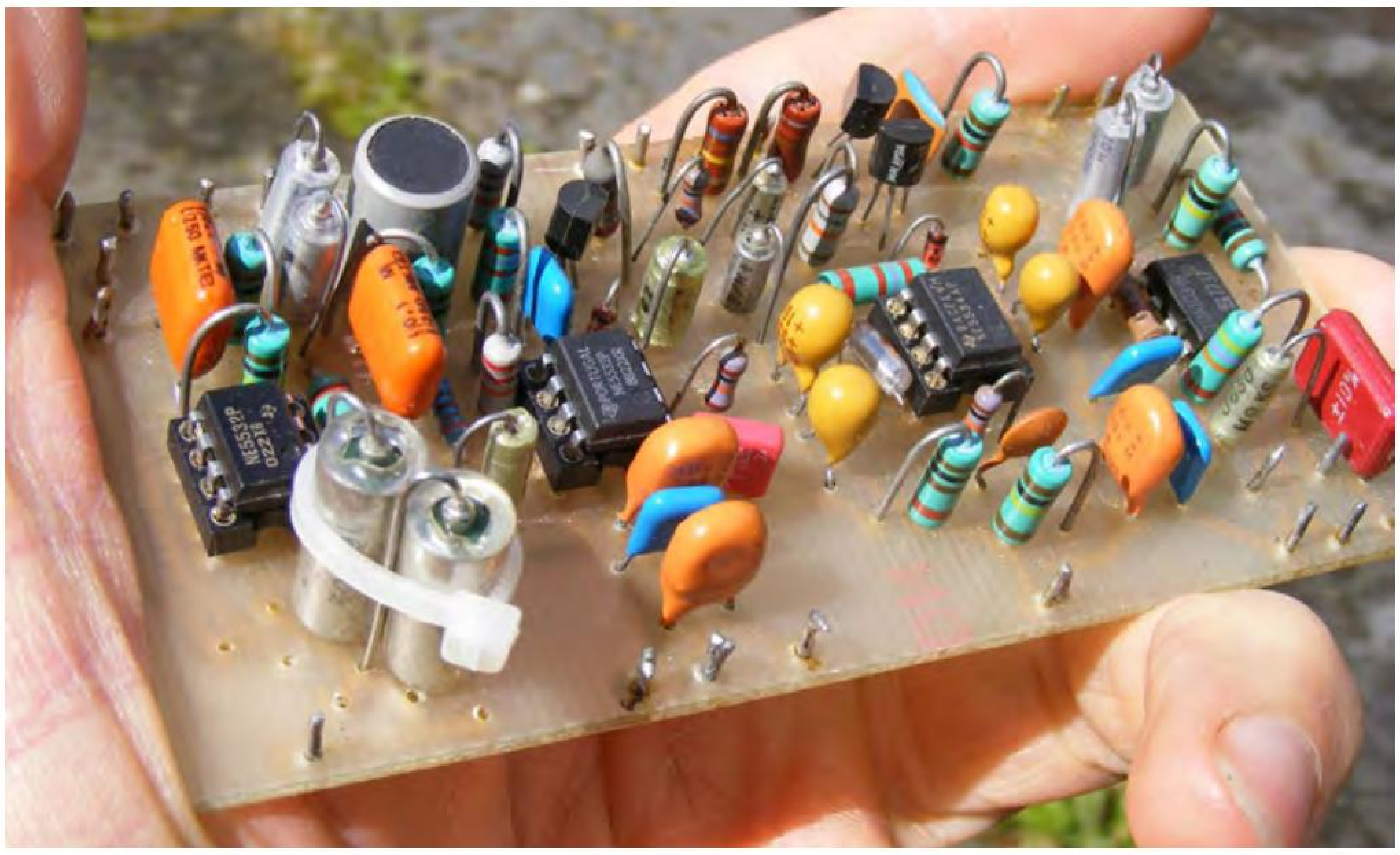


Fig.18. This mixer channel strip has been cooking in a hot rack since 1988. All the capacitors were perfect. Note the use of back-to-back tantalum capacitors and solid aluminium types for rail decoupling.

since 1988. It uses only solid capacitors. Note the use of back-to-back tantalum capacitors and solid-aluminium power rail decoupling capacitors.

Bi-polar solid tantalums are available, but rare and expensive. Nobody seems to make a bi-polar polymer capacitor, which is a pity as it could be the ideal audio capacitor – take note Panasonic! The old MnO_2 solid aluminium capacitors are almost semi-bipolar, having a 3V continuous reverse rating. They are so hard to blow up, they are ideal for capacitance substitution boxes. Their distortion performance is midway between wet electrolytic and solid tantalum types.

Biasing

Some engineers bias the centre connection of series back-to-back polarised capacitors and claim it reduces distortion further. I have not been able to replicate this. I found the system to generate its own bias voltage at high levels due to reverse leakage. Bateman says a small voltage around 1V to 5V is more beneficial than the conventional wisdom of using half the rated voltage. Of course, in single-rail circuits the capacitor is always biased at half-rail.

Solid capacitors are happy with no bias at all, such as in dual-rail op-amp circuitry. Their polarity is unimportant and they will tolerate small offsets up to around –1V continuously. They will also be fine with momentary reversals of 15 to 25 per cent their rated voltage. In the 1980s, when I worked as a test engineer at Brooke Siren Systems, their highly regarded FDS 360 crossovers had wet aluminium coupling capacitors that were back-to-back and biased in the middle. There was even an extra current displacement resistor to bias the op amps output into class A – see Fig.19 – total overkill.

Leakage

Another advantage of solid-tantalum capacitors is that their leakage current is typically 10× lower than wet aluminium types, resulting in less noise from pots and switches, especially just after turn-on if the equipment has not been used for a while. In this situation, the leakage currents of wet aluminium capacitors are initially high and have to settle down. The solid aluminium and aluminium polymer types have higher leakage than tantalums and exhibit some degree of settling. This means pull-down anti-click resistors on audio switches can be 10× higher if tantalum coupling capacitors are used, as shown in Fig.20.

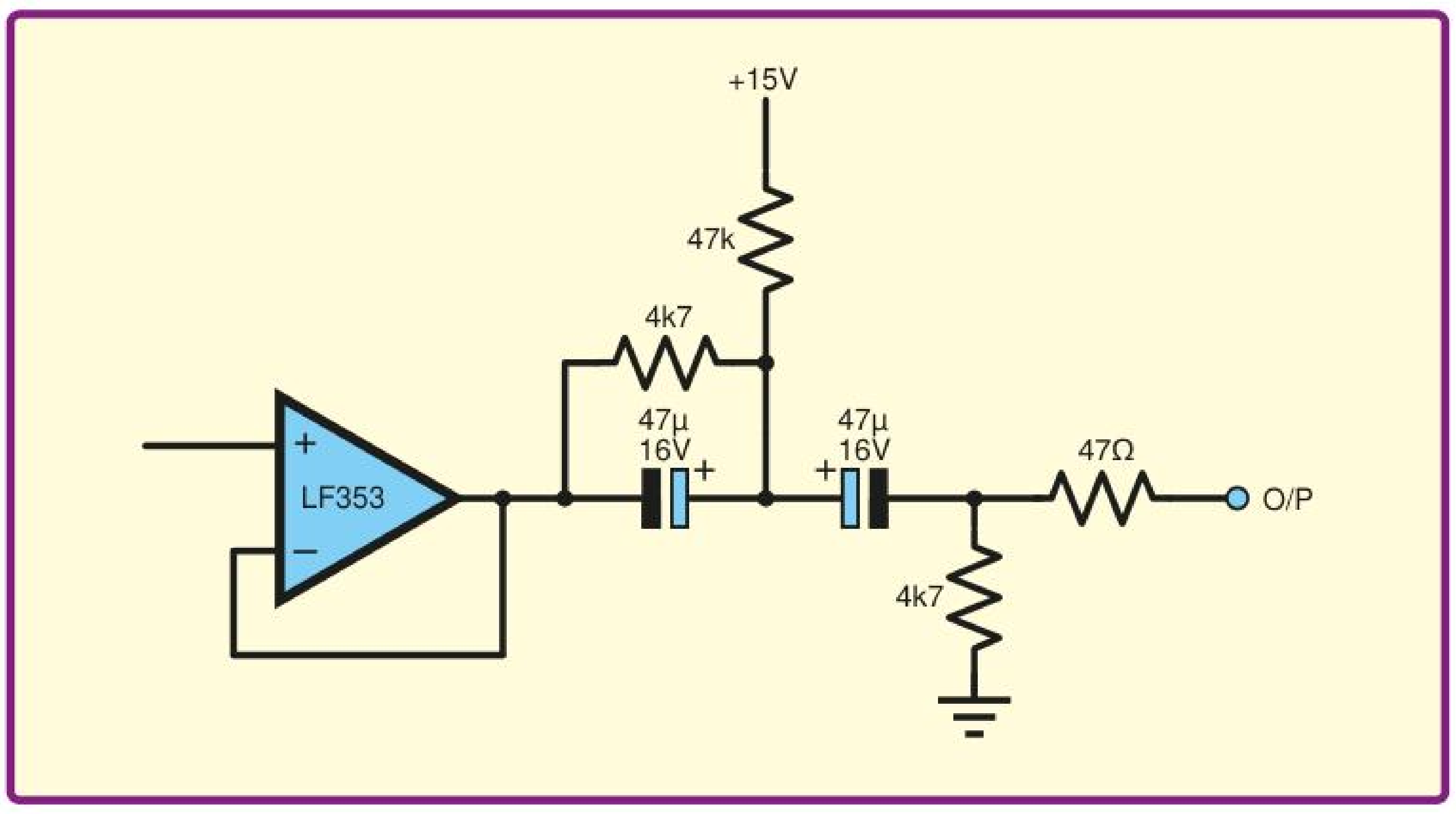


Fig.19. Brooke Siren Systems used to bias their back-to-back coupling capacitors with this special arrangement, which also biased the output of the op amp into class A.

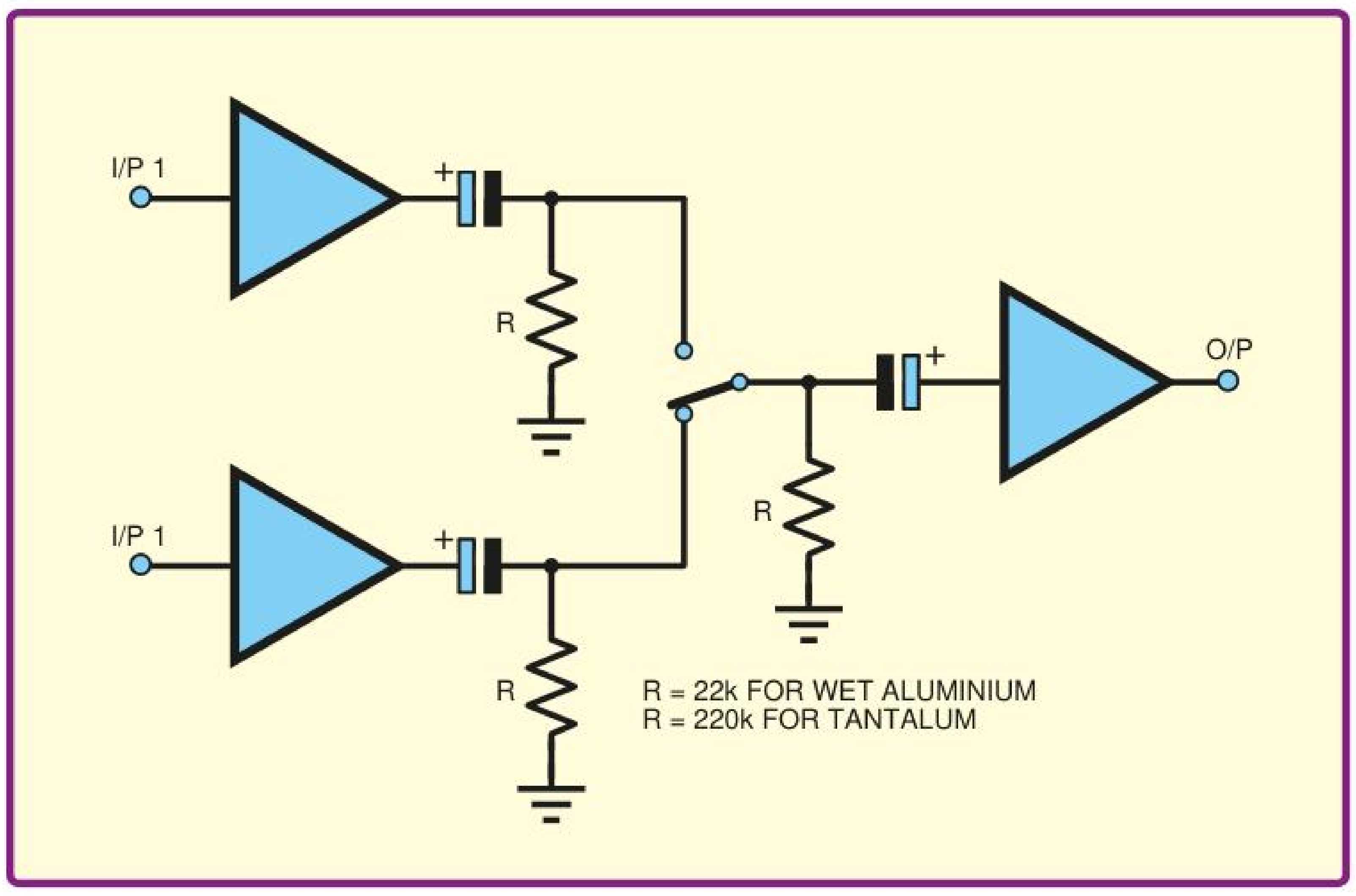


Fig.20. It is necessary to use 'anti-click' resistors to hold the voltage on the switch contacts at 0V. Since tantalum capacitors have 10× less leakage current than wet aluminium capacitors, the resistors can be 10× higher in value. The increased impedance may allow the capacitance to be reduced.

CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

Selecting the right op amp

LAST month, we started discussing the problem of selecting a suitable op amp in response to a question posted by ***741*** on the *EPE Chat Zone* forum. We looked at an overview of op amp operation, considering where real devices might differ from the ideal case. We also looked at the categories of the devices used by manufactures (such as the audio tag that ***741*** mentioned), and at how to find devices via on-line interactive selection lists. Once a possible device is identified, detailed information can be obtained from its datasheet. These are available as PDF files from manufacturers' websites.

As we mentioned last month, high op amp performance in one area may mean a device is less good in other respects; for example, there is usually a trade-off between DC accuracy and speed of operation. There are a number of limitations to op amp performance which might catch new designers unaware; for example, a device may have an apparently appropriate bandwidth, but will distort a large output signal if the slew rate is not good enough. This month, we will look at op amp characteristics and specifications in more detail, covering some of the key parameters which you will find on a data sheet.

Application areas

A typical data sheet will start with the headline specifications listing the device's best characteristics. There will often be a list of suggested application areas for which a device is suited; this is in effect the markets into which manufacturer is trying to sell the device. There will usually be a written overview of the op amp's key features. On the following pages the specifications will be listed in more detail, including the conditions under which certain figures apply. Performance may vary with supply voltage, temperature, frequency, etc, and you may need be careful about what conditions apply in your design. The specification list is often followed by sets of graphs which show in more detail how parameters vary. The datasheet may also include other information such as application circuits and packaging details.

The specifications given on op amp data sheets can be divided into electrical ratings (maximum voltages etc), signal handling (mainly for ac, but also dc signals) and offset-related (which particularly affect dc accuracy). We discuss these in turn. Fig.1 shows the op amp symbol with the input and output voltages labelled. An op amp amplifies the difference in voltage between its two inputs, so $V_{out} = A_v(V_2 - V_1)$, where A_v is the open-loop voltage gain, V_2 is the non-inverting input voltage and V_1 is the inverting input voltage. This was discussed in more detail last month, but V_1 and V_2 will be referred to frequently in the following discussion.

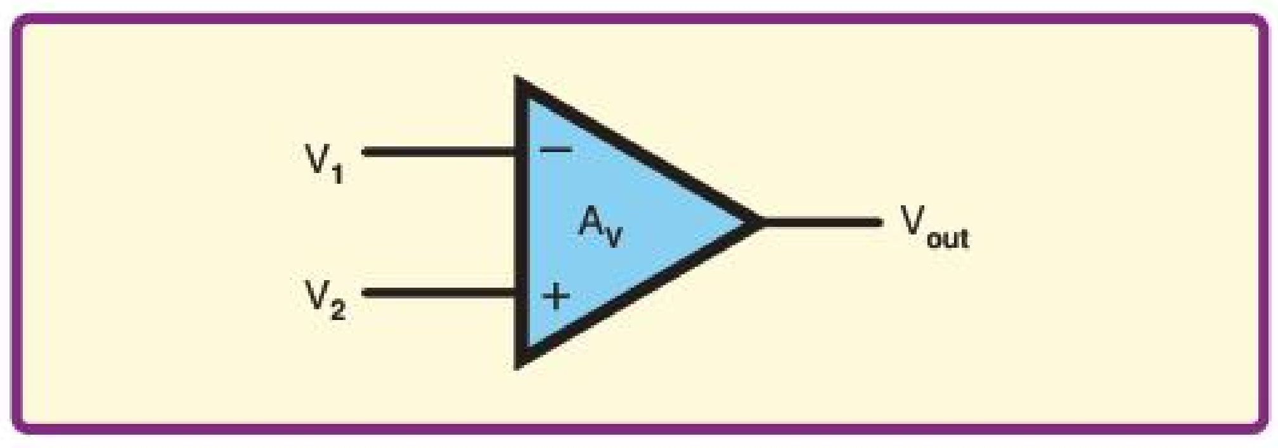


Fig.1. Op amp symbol

Electrical ratings

Maximum and minimum power supply voltage (or supply voltage range). Op amps are often used with split supplies (equal positive and negative supply so that ground (0V) is at the midpoint). However, single supply circuits (a positive supply and ground) are also very common. The maximum supply voltage is the total supply voltage, so it would be 30V for a split ±15V supply. The maximum supply is most typically in the range of around 3V to 30V, but there are a significant number of devices with supplies up to around 40V to 45V, and special high voltage op amps are also available for much higher voltages (hundreds of volts).

The minimum voltage is typically 3V to 10V for op amps with 30V maximum supplies, but this varies quite a bit. There are a number of low voltage op amps that have minimum supply voltages down to 1V or less. These are usually intended for low power applications. Exceeding maximum supply voltages can cause damage to integrated circuits due to excessive current flow and power dissipation.

Maximum differential input voltage. This is the maximum value of ($V_2 - V_1$) which can be applied. Typically this is equal to the supply voltage, and may be specified with respect to the supply. In some cases is may be a largish value such as ±40V, in others it may be much lower, less than ±1V, for example. You will need to take note of this if your application causes large differential inputs to occur.

In actual operation the differential input voltage is often very low due to the high gain of the op amp. Consider an op amp with a gain of one million operating on a ±10V supply. The maximum output voltage will be ±10V, which only requires a differential input of ±10µV (ten microvolts). A differential input larger than this will cause saturation.

Amplifiers, filters and similar signal processing circuits usually avoid saturation, but other circuits, such as comparators and some types of oscillator may use large differential inputs which switch the op amp between positive and negative saturation. Saturation should particularly be avoided in circuits that must operate at a high speed because the op amps take longer to recover from saturation than to respond to signals within their linear operating range.

Maximum input voltage. The maximum V_1 or V_2. Like maximum differential input voltage, this is often specified in terms of the applied supply voltage.

Power dissipation. This is the value of supply current multiplied by supply voltage. Power dissipation will increase as the power supply voltage is increased and if higher output currents are demanded from the op amp. The maximum power dissipation that can occur without causing damage is quoted, but this will depend on thermal conditions (heatsinks may be needed for special high power devices). If an op amp is available in more than one type of package these may have different power dissipation ratings. For special low power op amps, the minimum amount of power consumed in typical operation or no-signal (quiescent) conditions is often quoted as a selling point.

Supply current used and maximum supply current. This is the current into the supply terminal(s) under specified conditions. You need to distinguish between figures for maximum and quiescent conditions. Again, as with power dissipation, low operational supply current is often quoted as a selling point for special low power devices. Some low-power devices have a shutdown control that stops operation and reduces supply current to very low levels.

Output short circuit duration. The length of time output can be shorted to ground (0V), or the supplies, without causing damage to the op amp. For many devices this is infinity due to the inclusion of short-circuit protection circuitry inside the op amp.

Maximum peak-to-peak output swing. The maximum peak-to-peak output voltage that can be obtained without clipping the waveform due to saturation. For many devices this is very close to the power supply voltages.

Rail to rail. This term can apply to inputs, outputs or both, and indicates that the op amp's operating signal range is close, or equal to the supply voltage. This implies that the maximum input, common-mode and/or output voltages are rated at the supply voltage.

Signal handling

Open-loop voltage Gain (A_V). This is the gain in the basic op amp equation stated above. Ideally, A_V is infinite; in real op amps it typically ranges from tens of thousands to millions. The gain specified on data sheets is for low frequency operation and op amp gain is deliberately made to fall as frequency increases to prevent instability. As we noted above, the very high gain means that the differential input voltage in normal operation is very small.

Gain may be specified as a number eg, 100,000; as a ratio of voltages eg, 100V/mV; or in decibels, eg, 100dB; (these three example gains are the same). The gain in decibels is found by taking the gain as a number, taking the logarithm and multiplying by 20, eg, 100dB = 20log(100,000).

Although in some cases op amps with particularly high gains may be preferable, the precise value of the gain for individual op amps of a given type does not usually matter. This is because op amps are often used with negative feedback in circuits where the gain of the circuit depends on the external components and not on the gain of the op amp – gain just has to be large for the feedback components to dominate the circuit characteristics. This means that the fall in gain of the op amp with frequency does not affect the circuit until the very high frequencies at which the op amp's gain becomes low.

Common-mode rejection ratio (*CMRR*). This is the ability to reject signals common to both inputs – remember the op amp is a differential amplifier, so it should ignore signals which are the same on both inputs. Signals which are the same on both inputs are called common-mode signals – the common-mode input voltage is the average of the two input voltages, ie, $(V_2 + V_1)/2$. The ratio of output change to common-mode input change is called common-mode gain, A_{CM}. Ideally this is zero. *CMRR* affects the ability of the op amp to ignore noise common to both inputs and affects gain accuracy in some configurations. *CMRR* is particularly important in circuits processing low level signals or operating in electrically noisy environments. If circuitry and wiring is appropriately constructed noise picked up from external sources will be similar at both op amp inputs and can be rejected. *CMMR* is given by A_V/A_{CM} and is usually stated in dB, values of 80 to 120dB are fairly typical, but lower and higher values occur.

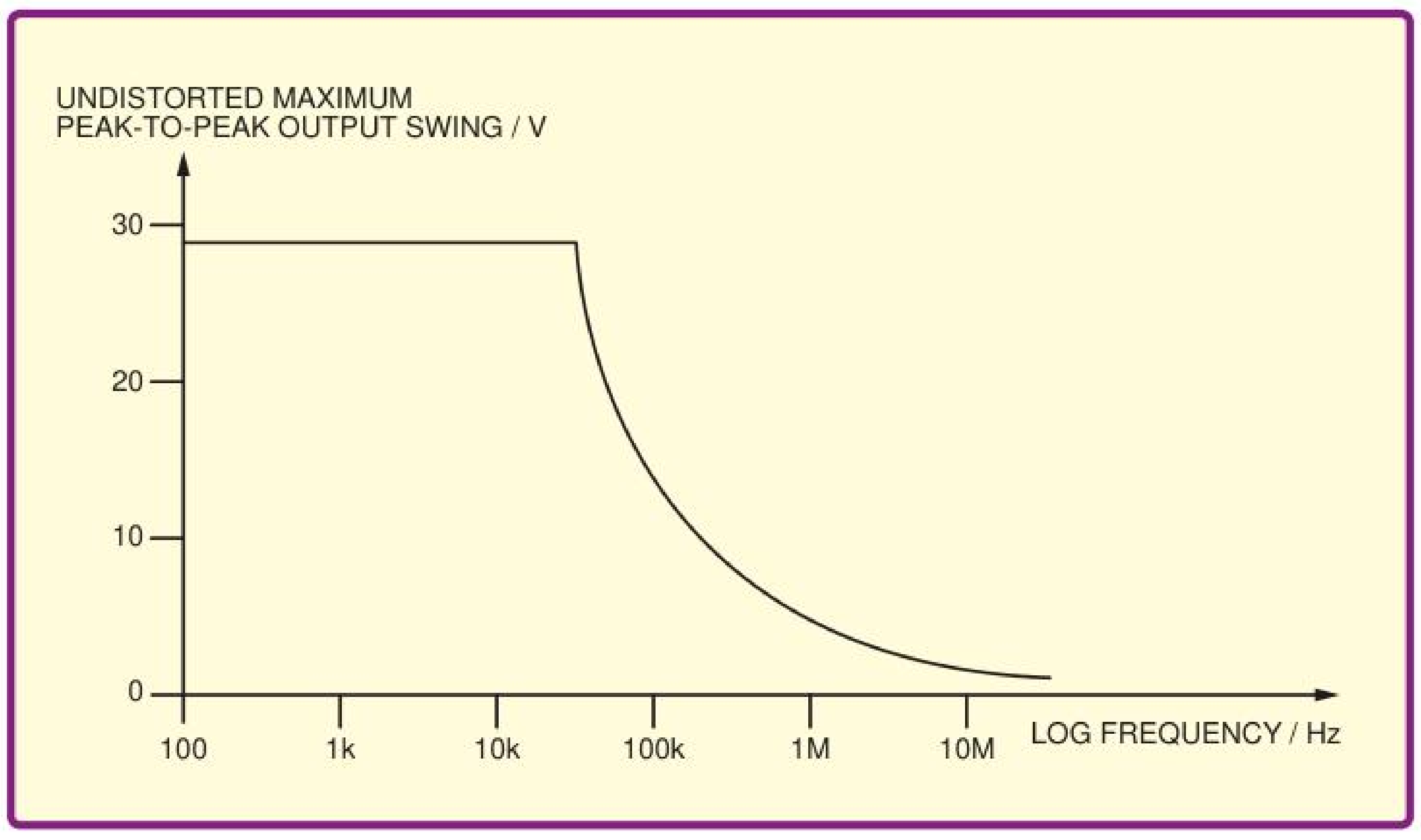


Fig.2. This shows the maximum undistorted peak-to-peak output amplitude for a sine wave from a typical low speed general purpose op amp operating on a ±15V supply (actual figures would depend on the device and supply voltage used).

Unity gain bandwidth (f_u) or **gain bandwidth product** (*GBW*). The range of frequencies for which open-loop gain is greater than one. Typical values for general purpose devices are in the range of tens of kilohertz to a few megahertz, but may be higher – into the gigahertz range for special high frequency/high speed devices.

Slew rate and full power bandwidth. Slew rate is the maximum rate of change of output. Slew rates are often quoted in volts per microsecond. For example, a value of 2V/µs would mean that the time that the op amp's output took to change from 0 to 5V, due to a step change at the inputs, would be 2.5µs. Typical slew rates for general-purpose devices are from a few hundred millivolts to a few volts per microsecond, but much faster devices are available with slew rates of hundreds or thousands of volts per microsecond. A fast device with a slew rate of 1200V/µs could change its output from 0V to 5V in 4.2ns.

The easiest way to think about slew rate is in terms of the response time to step change, as illustrated by the above examples. However, slew rate also determines the maximum peak-to-peak undistorted output for any type of waveform, including pure sine waves. At lower frequencies the maximum undistorted output is usually determined by the power supply voltage, but as frequency increases the op amp's output cannot move fast enough to 'follow the shape' of large amplitude waveforms (see Fig.2). If the required peak output voltage is V_m and the slew rate is S (in volts per second) the maximum frequency sine wave that can be output without distortion is

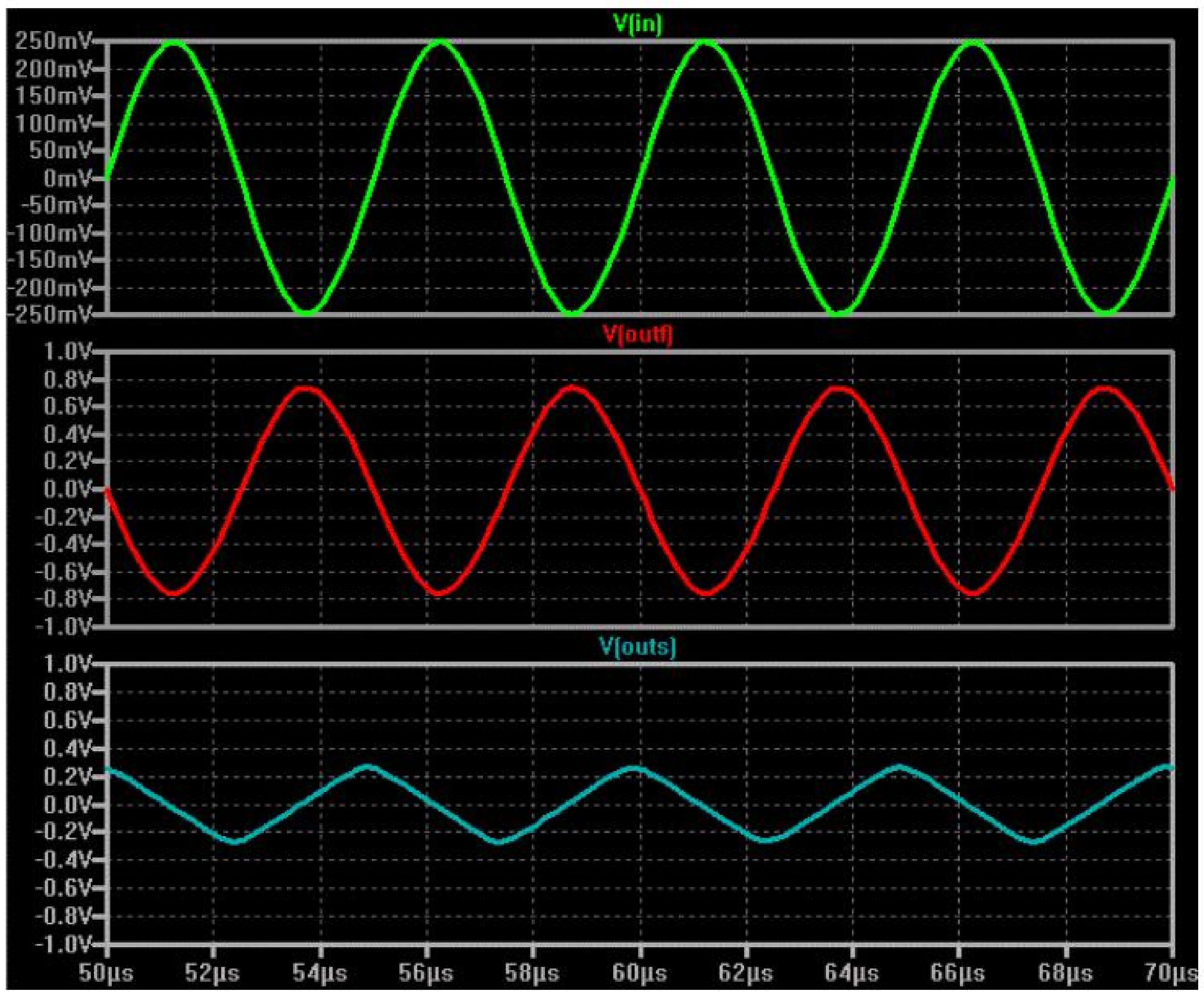
$$f = \frac{S}{2\pi V_m}$$

For example, for 2V/µs and 15V this is 21kHz, not a particularly high frequency. When V_m is the op amp's maximum output f is referred to as the full power bandwidth. An example of the effect of slew rate limiting is shown in Fig.3, where simulations of a fast and slow op amp are compared.

Power supply rejection ratio (*PSRR*) (or power supply sensitivity). This is the ability to prevent changes in supply voltage from causing changes in the output voltage. Changes in supply current, due to changes of load or activity in other parts of the circuit, cause changes in supply voltage. This is due to voltage drops in the supply wiring resistance, or internal resistance or lack of perfect regulation in the power source. *PSRR* is typically stated in decibels and defined in a similar way to *CMRR*.

Input resistance/impedance. Common-mode input impedance is the effective impedance from either input terminal to ground and is ideally infinite. Differential Input Impedance is apparent impedance between the inputs (also ideally infinite). The input impedances will take the form of capacitance in parallel with resistance. Sometimes the capacitance is not considered and only resistance is quoted. Input capacitances may also be quoted separately. FET-input op amps have particularly high input resistance (eg, $10^{12}\Omega$). Input impedance, however, is often not the main concern as the effective input impedance is increased by the use of negative feedback amplifier configurations. It is therefore bias currents which are often more important.

Output impedance. The output voltage given by $V_{out} = A_V(V_2 - V_1)$ is effectively connected to the device's output via a source impedance, or output impedance. At relatively high output currents (for the device in question) significant voltage drop may occur across this resistance. However, the effective output resistance is often reduced significantly when the op amp is used in a circuit with negative feedback. This is often helpful of course, but as signal frequencies increase the op



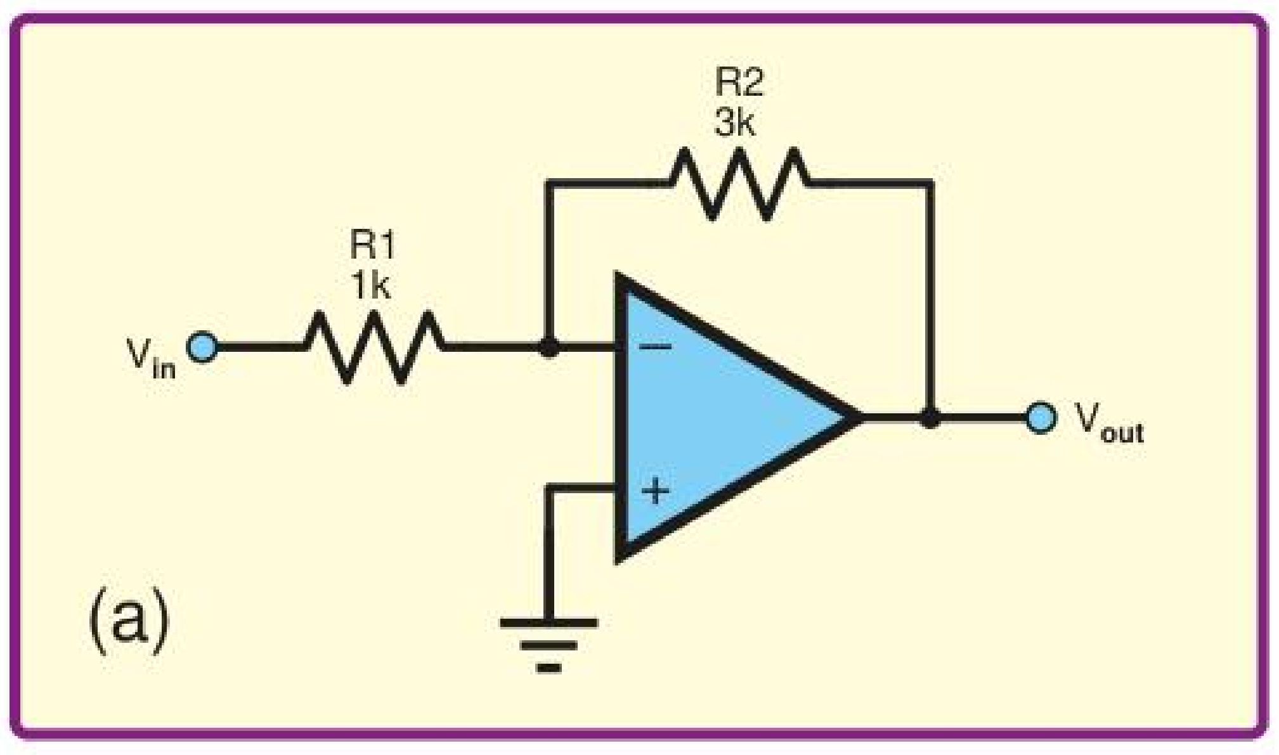
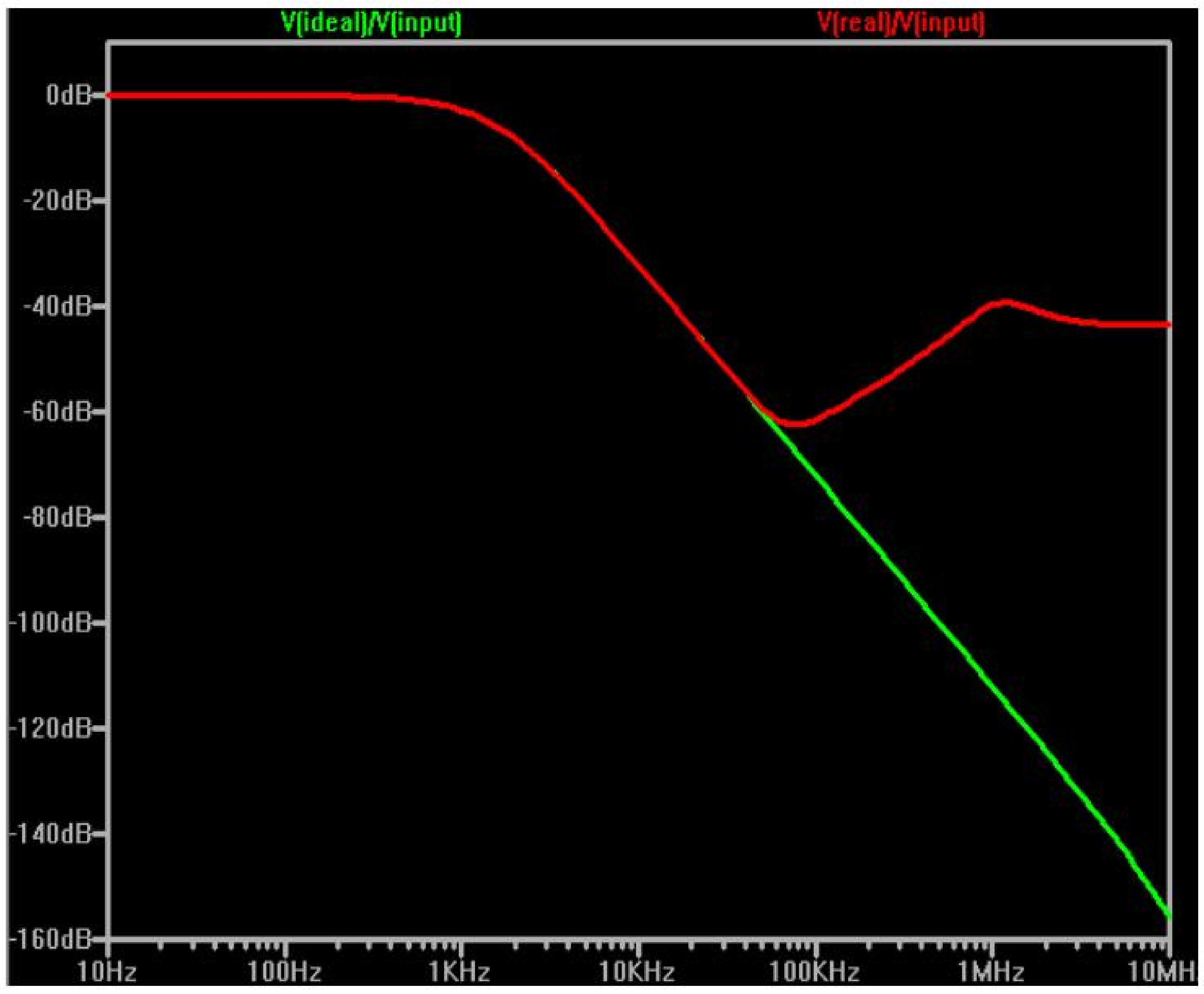


Fig.3a. (a) Simulation of an inverting amplifier (with gain three). (b) Comparison of a fast (LT1817) and slow (LT1001) op amp. The top trace is the input the bottom trace is the output from the fast op amp and the middle trace is from the slow op amp show slew rate limiting.



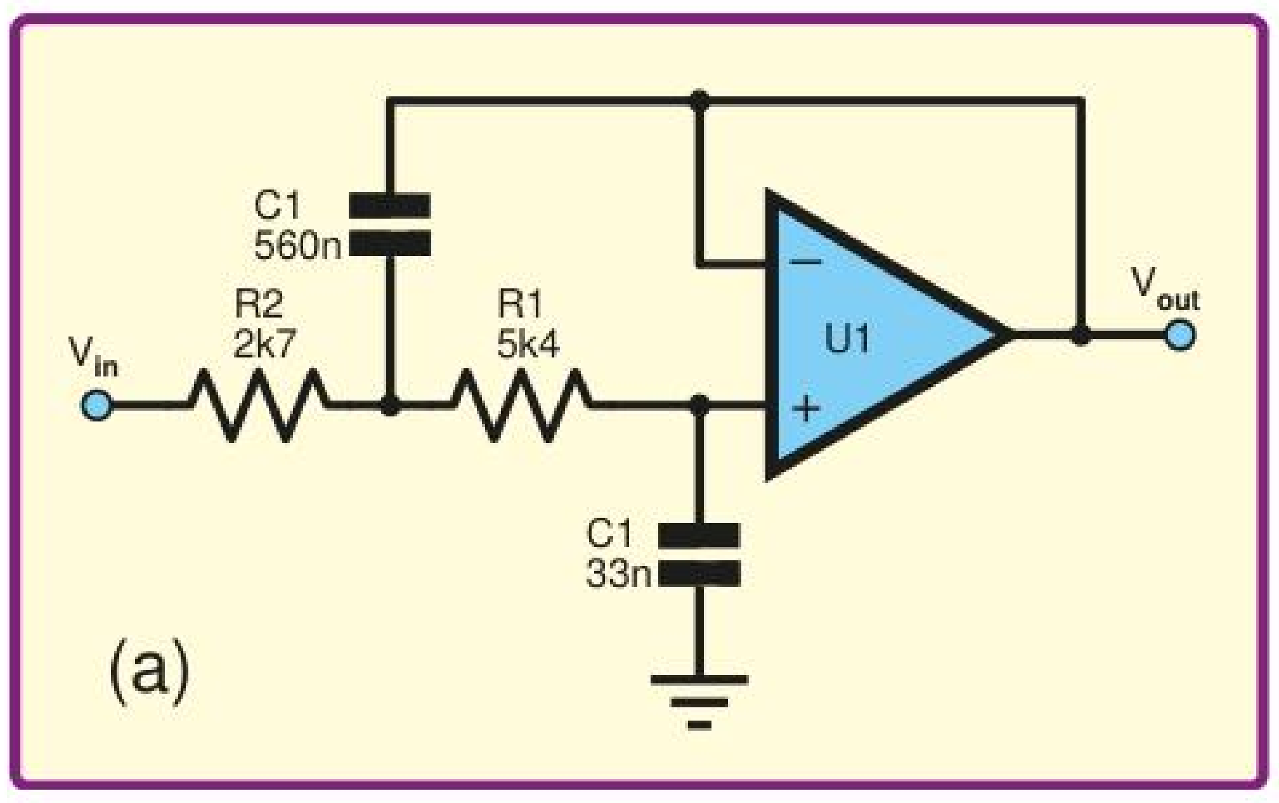


Fig.4. Simulation showing problem resulting from op amp output impedance in a Sallen and Key filter. (a) Schematic. (b) The green curve is the ideal response; the red curve is the response of the filter with the real op amp.

amp's gain reduces, reducing the impact of the feedback and hence the reduction in effective output impedance. In some circuits the increase of output impedance at high frequencies may be important; an example of this is shown in Fig.4. This was discussed in much more depth in the *EPE* Nov '11.

Offsets and bias

Input offset voltage (V_{IO}). Ideally with a differential input of zero the op amp's output should also be zero, but in real op amps there will typically be a non-zero output. The offset voltage is defined as the DC voltage which must be supplied between the inputs to force the quiescent (zero input signal) open-loop (no feedback resistors) output voltage to zero. The offset can be regarded as DC noise in any op amp circuit processing DC signals. The offset cannot be distinguished from the wanted signal and is processed by the circuit. The offset is typically small, but will be amplified by the circuit and may cause significant problems.

In op amp applications in which only AC signals are of interest, offsets are less likely to be a problem as they simply cause a shift in operating point. Some op amps have offset adjustment circuits (see Fig.5) that allow an external trimmer potentiometer, connected to the appropriate pins, to be used to set the output voltage to zero. The problem with this approach is that offsets can drift with time and are quite temperature sensitive. Low offset op amps must be used in circuits where good, sustainable DC accuracy is required.

Temperature coefficient of input offset voltage. Specifies how V_{IO} changes with temperature. As we noted above, offset changes with temperature and this parameter tells you by how much.

Input bias current (*IIB*). Inside the op amp there are transistors connected to the inputs, these require bias currents, and/or there are leakage currents through the chip structures. The input bias current parameter tells you how large these currents are and is defined as the average current into the two inputs with the output at zero volts. This can vary greatly for different types of op amp, from femtoamps (10^{-15}A) to tens of micoamps, with bipolar op amps having larger input bias currents than FET-input op amps.

Bias currents flow in the external components connected to the op amp (eg, the resistors used to set the gain) and in doing so cause voltage drops. If these voltage drops are not equal at the op amp's two inputs the difference will be amplified by the op amp and appear as a DC error at the output. This effect can be minimised by adding a resistor to one of the inputs to balance the resistance through which each bias current flows. This is illustrated in Fig.6. The bias current to the inverting input flows through R1 or R2, so making R3 equal to the parallel combination of R1 and R2 will result in the same voltage at the two inputs due to the bias currents (assuming the bias currents are equal).

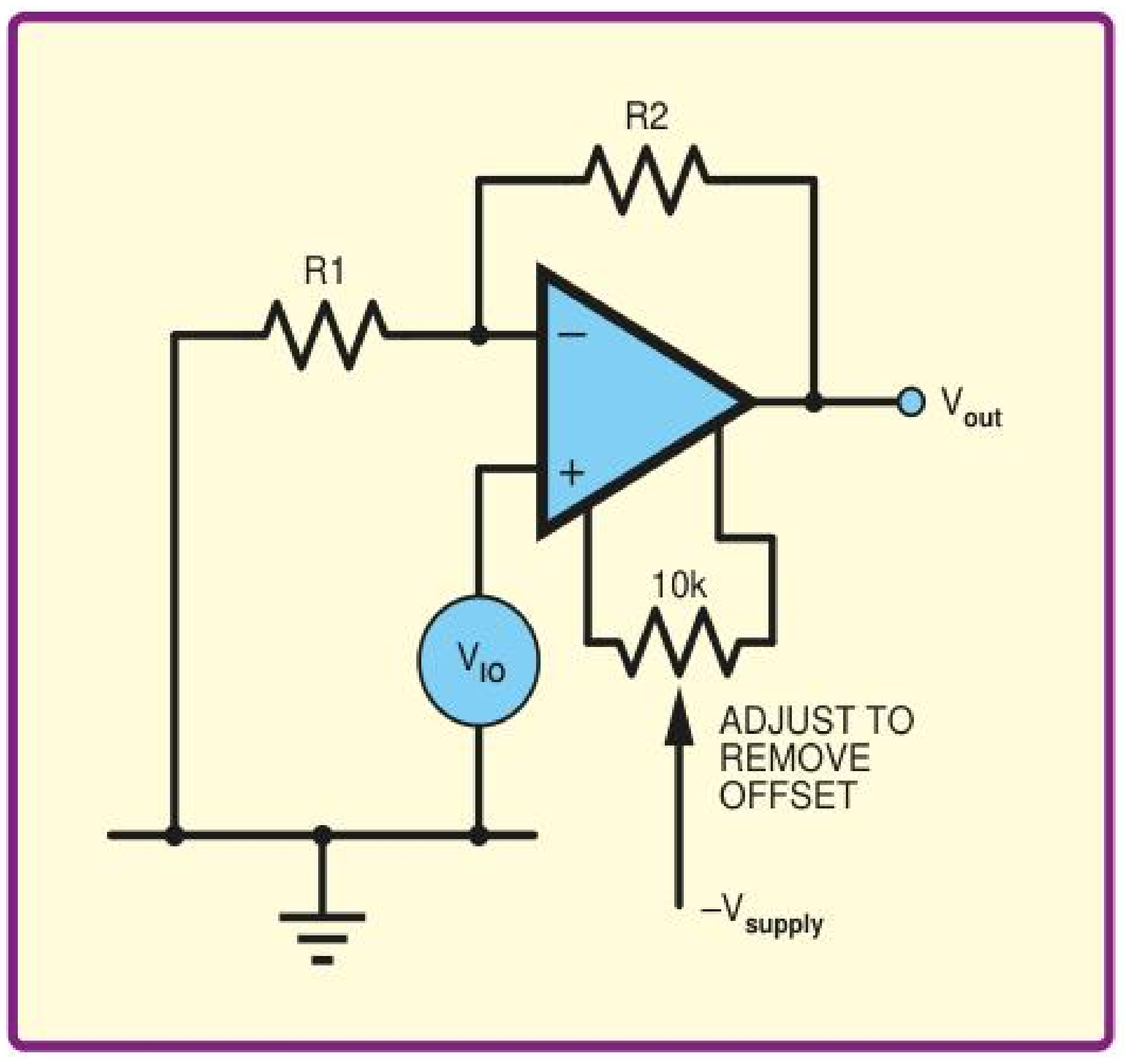


Fig.5. Offset adjustment

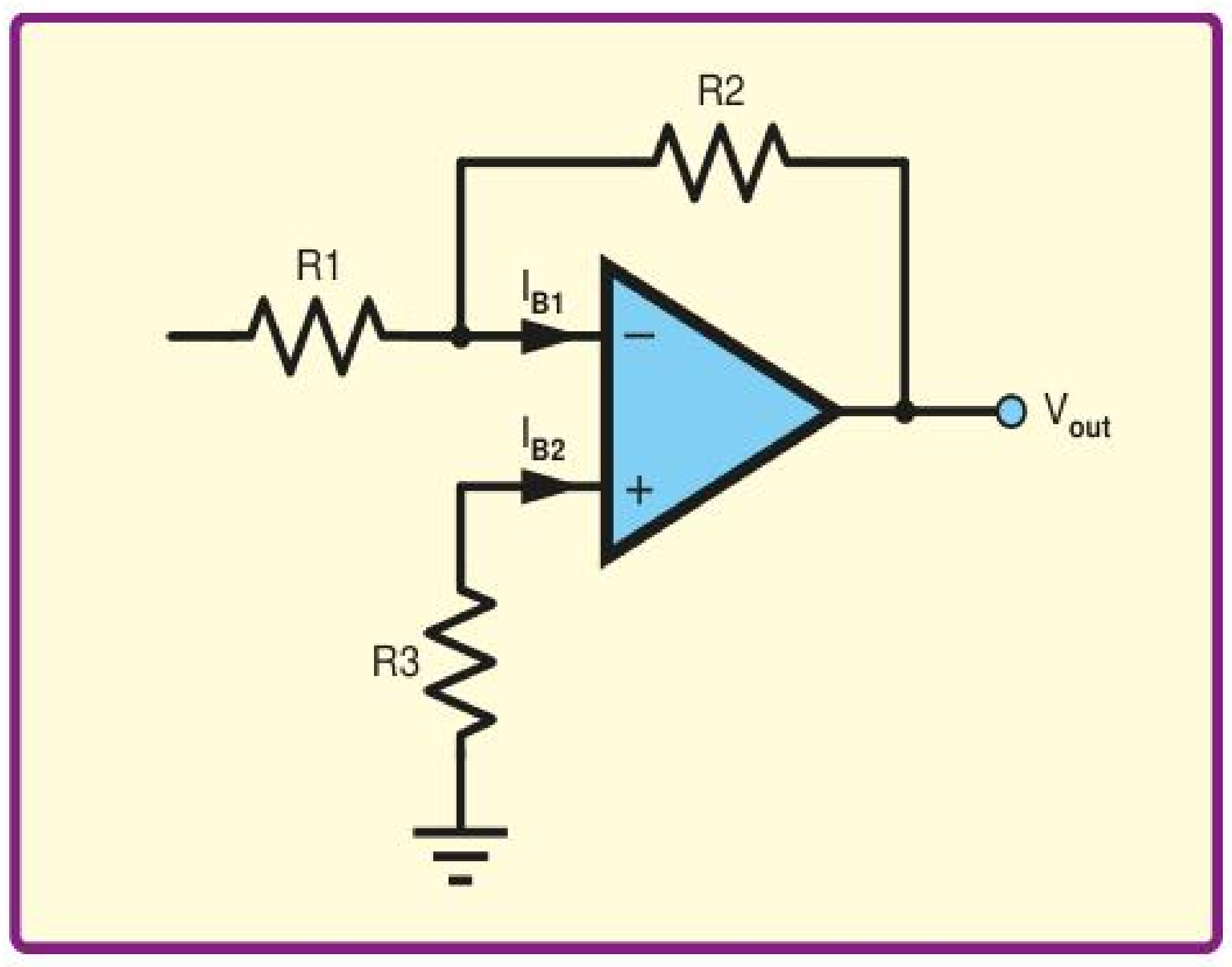


Fig.6. Minimising offsets due to bias currents

Input offset current (I_{IO}). This is the difference between the currents into the two inputs with output at zero volts, that is ($I_{B1} - I_{B2}$) where I_{B1} and I_{B2} are the input currents for the two inputs. Ideally these currents will be equal, but in practice they are not, so I_{IO} will be non-zero. The input currents have to flow through the external circuitry and will cause offsets even if the impedances connected to the two inputs are equal.

Temperature coefficient of input offset current. This specifies how I_{IO} changes with temperature.

Max's Cool Beans

By Max The Magnificent

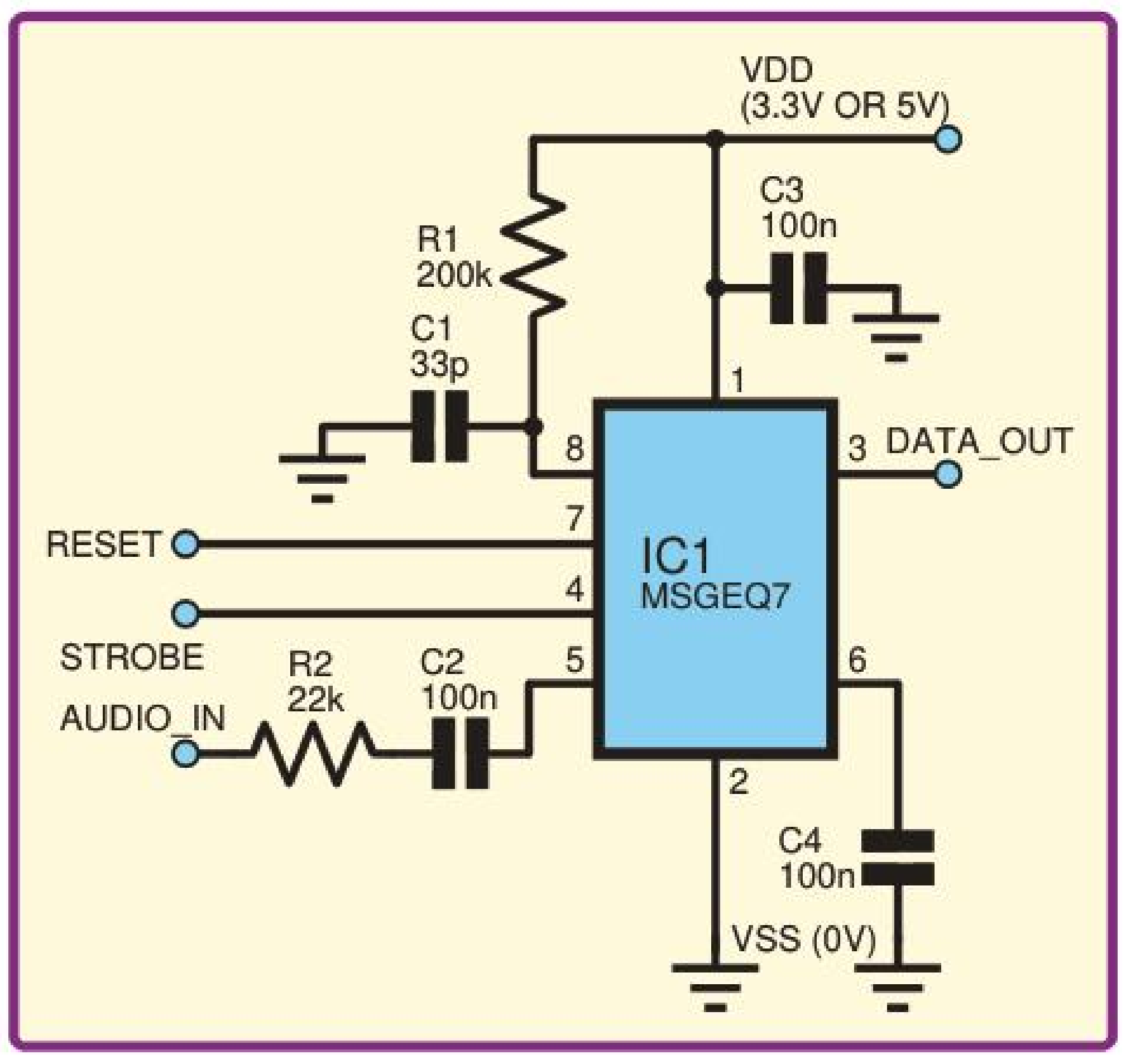
Mighty things from tiny chips!

As you may recall, I'm currently having a great time working on my Bodacious Acoustic Diagnostic Astoundingly Superior Spectromatic (BADASS) display hobby project. My plan is to use an 8-bit, 16MHz Arduino Mega microcontroller (MCU) development board (**http://bit.ly/1gEbS2r**) to drive the display itself. Meanwhile, I'm going to use a 32-bit, 80MHz chipKIT Max32 MCU prototyping platform (**http://bit.ly/1uf8Tnr**) to analyse the audio data. The great thing about the chipKIT is that it has the same physical footprint and input/output (I/O) pin mapping as the Arduino; also, their IDE's are almost identical, which makes my life easy.

My original plan was to run a digital signal processing (DSP) algorithm, such as an FFT (fast Fourier transform) on the chipKIT. But then my chum Steve Manley introduced me to a cunning little chip called the MSGEQ7, which is available for only $4.95 from the chaps and chappesses at SparkFun (**http://bit.ly/1jRKv3C**).

Inside the MSGEQ7 are seven band-pass filters tuned to 63Hz, 160Hz, 400Hz, 1,000Hz, 2,500Hz, 6,250Hz, and 16,000Hz. Each of these filters has an associated peak detector. The clever thing is that the outputs from the seven peak detectors are multiplexed onto a single DATA_OUT pin, which allows the whole thing to be compressed into a tiny 8-pin dual-in-line (DIL) package.

So the MSGEQ7 sits there happily sampling the audio signal coming in and working out the peak values of the seven frequencies (of course there is some overlap from one band to the next). Whenever we wish to check on the current 'state of play,' we use the digital RESET and STROBE signals. Personally, I think that RESET is not the best name, because it seems to imply a reset of the entire chip. My understanding, however, is that all it does is reset the internal multiplexer and latch in the current frequency band values. 'But you can't fight city hall', as they say, so we'll use the manufacturer's terminology. A positive-going pulse on the RESET signal kicks everything off. Although the datasheet doesn't actually say so, my impression is that this pulse takes a copy of the current peak detector outputs and stores (latches) these values. We then apply seven negative-going pulses to the STROBE input. Every time the STROBE input goes low, we can read the value of one of the bands on the DATA_OUT signal, starting with the 63Hz value and working our way up to the 16,000Hz value. Speaking of which, DATA_OUT is an analogue value, whose magnitude reflects the value from the corresponding peak detector. This value can be read using one of the microcontroller's analogue inputs.



A handful of resistors and capacitors (and a microcontroller) are all it takes to get up and running

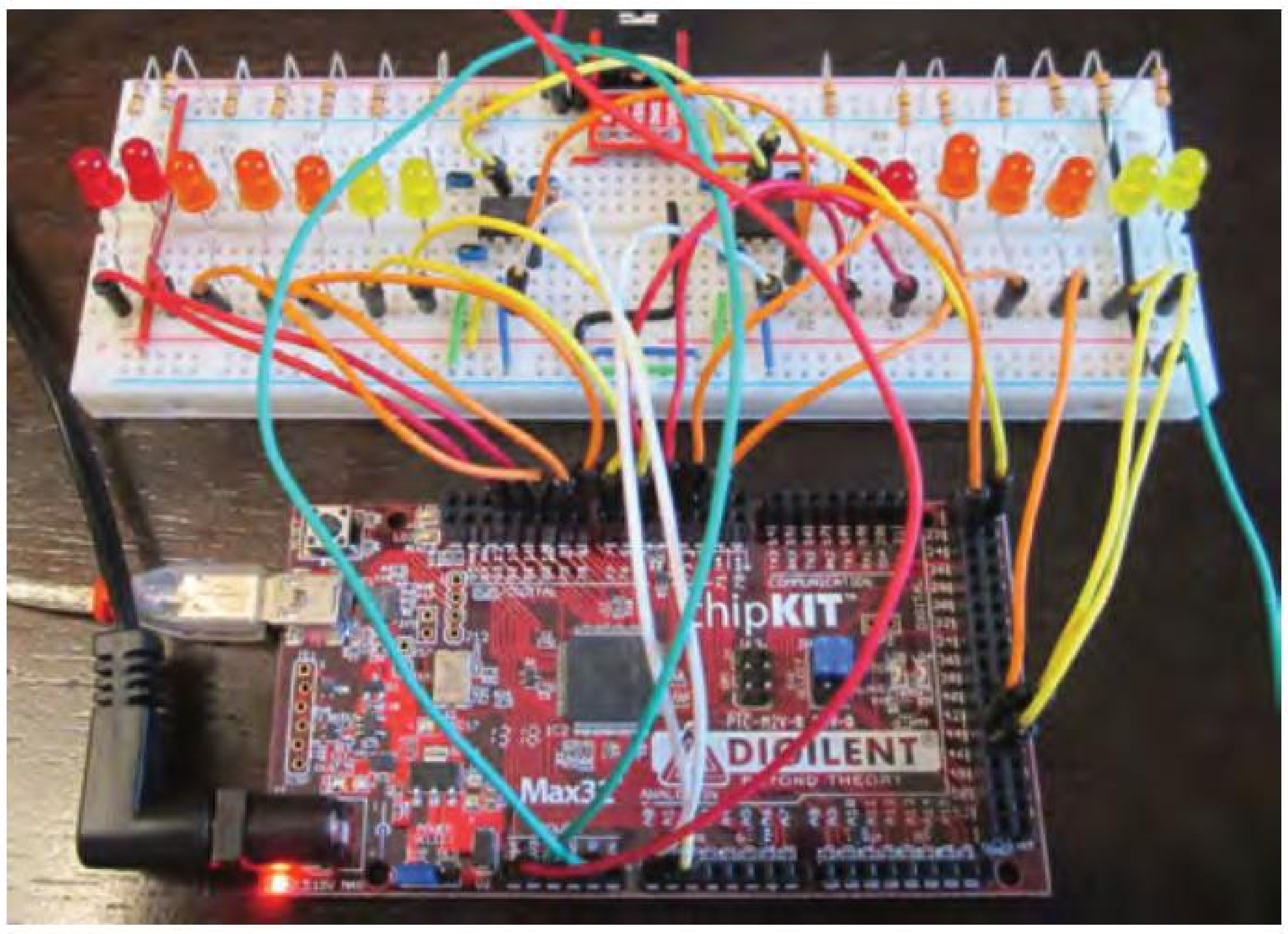
The simplest things can trip you up

When I started this project, I ordered a PCB-mounting audio jack from one of the usual parts suppliers. I foolishly assumed that since this was classed as a PCB-mount, it would, a) have a traditional 0.1-inch pin pitch and, b) the pins would be long enough to use on my breadboard. I was wrong on both counts. I ended up bouncing back over to the SparkFun website and purchasing a 3.5mm PCB audio jack (**http://bit.ly/1oATQkH**) along with an associated breakout board (**http://bit.ly/1kQYTtd**).

First of all I placed the audio jack/breakout board combo and the two MSGEQ7s, then I added the other components, then the wires, and finally I added the flying leads connecting the breadboard to the chipKIT MAX32. My first test involved playing a Mumford & Sons track through the MSGEQ7s, reading the band values into the chipKIT, and writing them back out again to a serial I/O window on my notepad PC. You can see a video of this on YouTube (**http://youtu.be/rLsBDZgd3KQ**).

Next, I added fourteen LEDs; seven each for the left and right channels. I controlled these using fourteen PWM (pulse-width modulated) digital outputs, so the brightness of an LED reflects the amplitude of its associated frequency band. Just to add a little visual interest, for each channel I used two red LEDs for the lower frequency bands, three orange LEDs for the middle frequency bands, and two yellow LEDs for the higher frequency bands. You can see a video of the result in action playing Supertramp on YouTube (**http://youtu.be/qJyX3S9CmDc**).

I must admit that I'm really rather pleased with the result. This is only a small step on the way to the full-up BADASS display, but the fact that everything worked the first time brought a great big beaming smile to my face. If you are interested in doing this yourself, I've written a step-by-step guide that explains everything in excruciating detail! (**http://ubm.io/VXKuau**). Until next time, have a good one!



PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

The *PIC n' Mix* Kickstarter

We pause the series this month to talk about the Kickstarter website, and how we brought the LPLC development board to life.

Unless you have been living on a desert island these last few months, you will be aware of our adventures in Kickstarter land, but for those who aren't familiar and for the purposes of completeness we will start this story from the very beginning.

It all began back in January of this year when a reader of the *Pic n' Mix* column contacted the magazine, asking if he could purchase a development board rather than make one himself. Our reaction at the time was 'well, we would need about one hundred other people to be interested to get the component and board costs down. Manufacturing a board for one or two people just wouldn't be cost effective.'

And then the penny dropped. This is exactly what Kickstarter is for!

What is Kickstarter?

Launched early in 2009, the Kickstarter website was developed by a group of friends who wanted to help music bands and other creative groups secure funding for gigs, shows, films and similar projects requiring a large up-front commitment. It works by providing a platform to promote the idea – the Kickstarter website – and asking people to commit financial support. A group would say, 'We need £10,000 to make this film, back us with a £10 donation and you will received a DVD of the film once it is made.' People register their credit card details, and only if the required amount has been pledged within the selected timeframe (generally 30 to 60 days) will their cards be debited. If the pledges fall short – even by a single penny – then the project is cancelled, and no funds are debited. That aspect can be a bit harsh, but it makes sense – if you say you need £10,000 pounds to make it happen, then it's that amount or nothing. Project funding 'runs' for the full length of the time specified, even if it reaches its required funding level early. Many successful projects exceed their funding goals, some of them significantly.

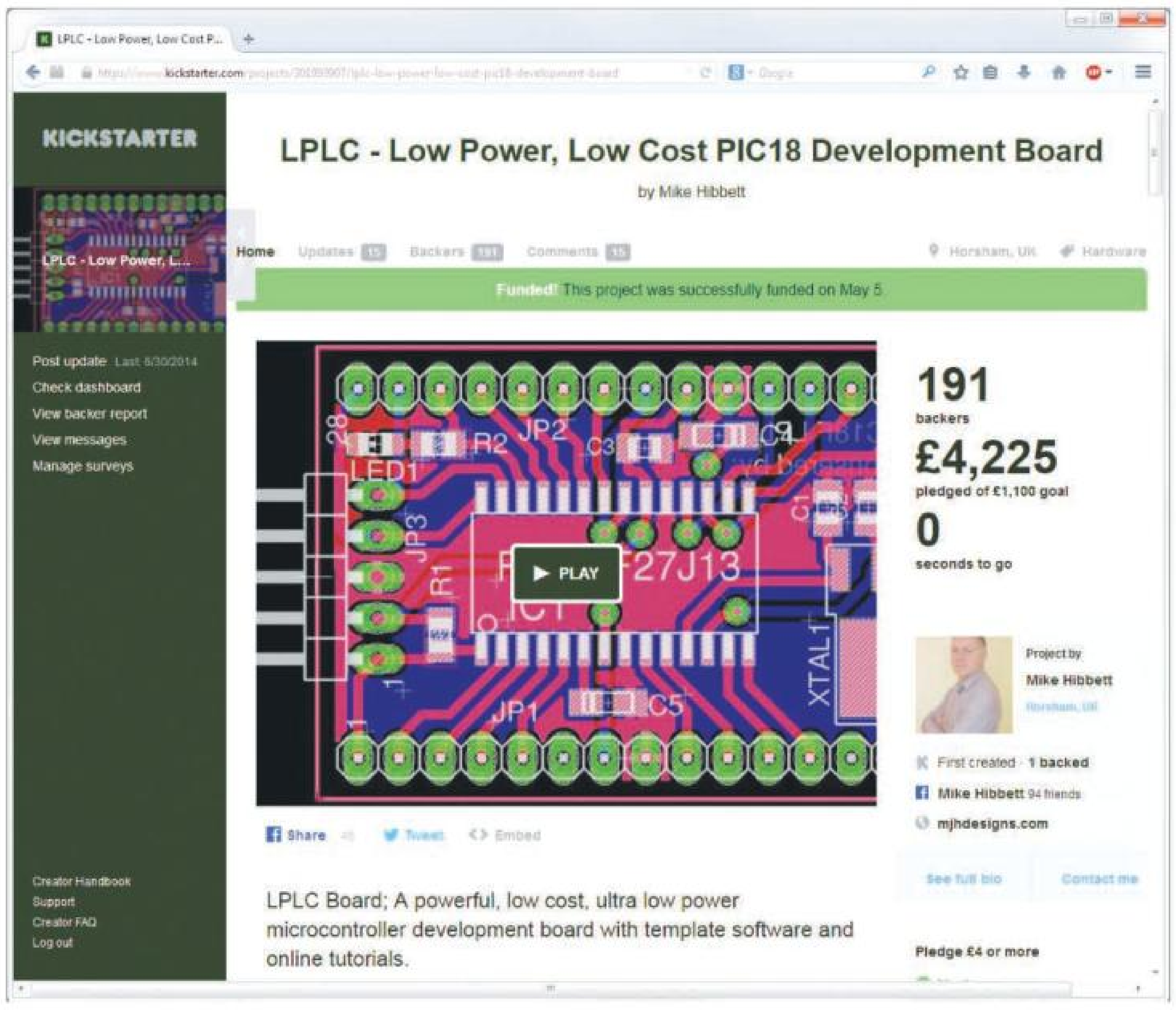
Although originally launched for the arts, Kickstarter has found significant interest in technology and product manufacturing areas. It's no surprise; much of the costs involved in product manufacture are up-front non-recurring expenses to pay for project specific tooling, and with PCBs in particular, the price for 200 boards is only a few pounds different to 600.

There have been some amazing products developed from an initial Kickstarter project; two notable ones are the 'Pebble Smart Watch', which asked for 100 thousand USD but received 10 million, and the 'Oculus Rift' virtual reality headset, which asked for 250 thousand USD, received 2.5 million USD, but were then bought by Facebook for an astonishing two billion USD. Kickstarter has seen over 65,000 projects successfully funded, and in the five years they have been operating over one billion USD has been pledged. Clearly, there's gold in them hills!

Our project was somewhat more modest; we asked for one thousand pounds (100 boards, selling for 10 pounds each) and received just over four thousand pounds for a total of 430 boards. It was just about the perfect quantity; large enough to make the costs reasonable, and small enough to avoid assembly being a complete nightmare. Had the quantities been much higher we would have been forced to subcontract out the assembly and delivery, which would have made the project far more complicated.

How does it work?

Each submitted project gets its own page on the Kickstarter website, with a description of the project, a clear statement of the objectives and funding required, a video presentation and a list of the various and unique pledge levels the project is offering. A pledge is a simple 'Pay this much, and you will receive this reward in return.' It can vary from as little as 'our sincere thanks' to one or more products. A project may have as many or as few pledge levels as the creators wish. You can see our project's page in Fig. 1 and the ultimate goal, the LPLC board, in Fig.2.



LPLC - Low Power, Low Cost PIC18 Development Board

by Mike Hibbett

Funded! This project was successfully funded on May 5

191 backers

£4,225 pledged of £1,100 goal

0 seconds to go

Project by Mike Hibbett

First created · 1 backed

Mike Hibbett 94 friends

mjhdesigns.com

LPLC Board; A powerful, low cost, ultra low power microcontroller development board with template software and online tutorials.

Pledge £4 or more

Fig.1. Kickstarter project page

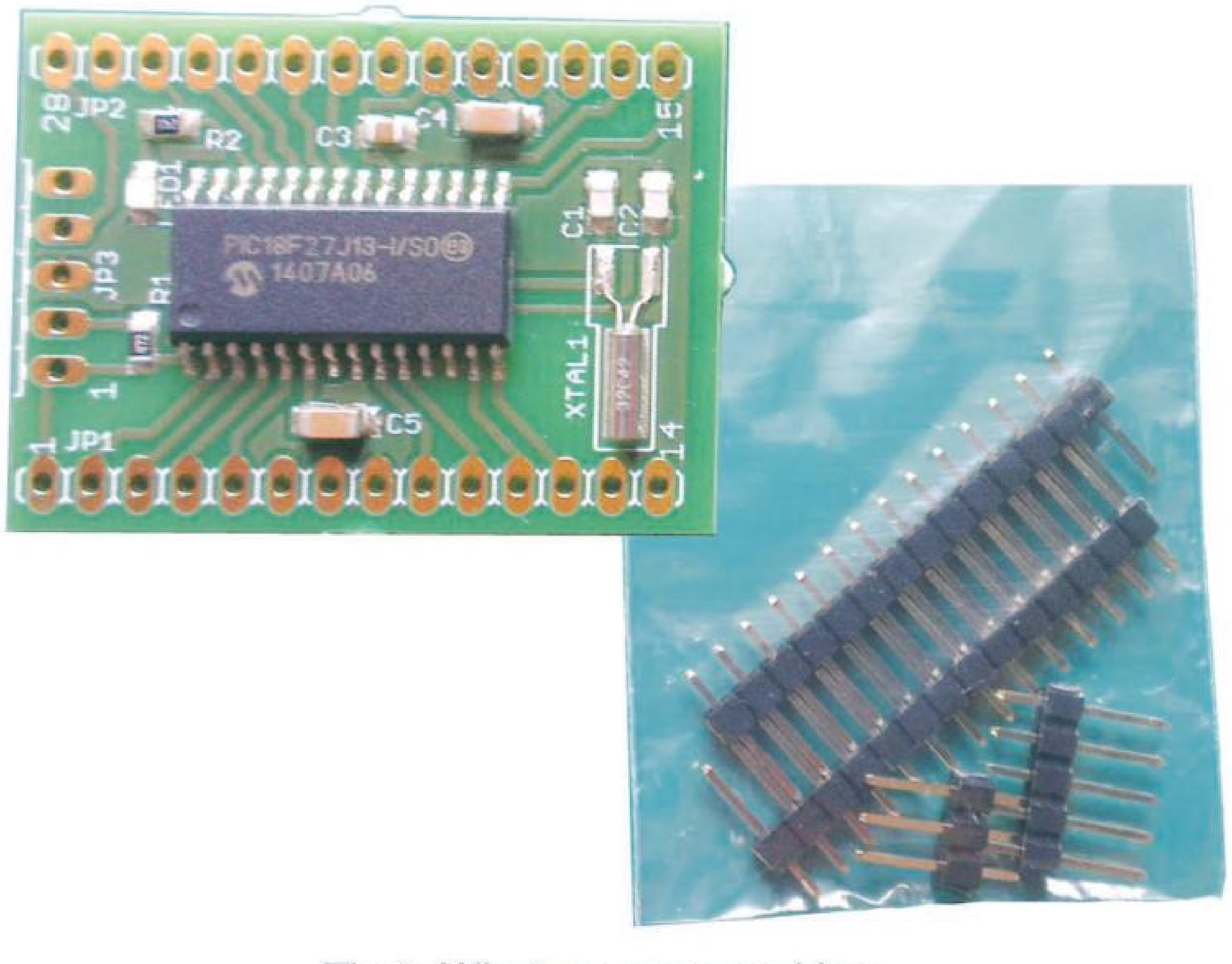


Fig.2. What we were making

The web page provides an indication of funding progress, and holds updates posted by the project creators. A pledge may be withdrawn right up until the final seconds of the project funding period, and funds are only taken from the credit card if the minimum amount required has been raised. Kickstarter takes an approximate 10% cut in the full funding collected, then passes the remaining amount on to the project creators.

At this point, Kickstarter withdraws from the proceedings and the responsibility lies with the project team to take that money and use it to deliver the rewards. There is no easy way to get your money back if the project team 'do a runner', and this has happened on occasion. It's for this reason that it is important to develop your credibility with the audience, through good update reports and responding to questions, otherwise people may not wish to take the risk, even if the amount pledged is relatively small. Fortunately for us, the *Pic n' Mix* column and the connection to the magazine provided a degree of 'technical authority' and respectability, but only among the readership. We still had to work hard providing regular updates.

Kickstarter provides some great statistics for the project creators and in particular the funding progress graph, as shown in Fig.3, gives some interesting insights into the way projects get funded. In the first few days there is a flurry of interest as the people who already know that you are running the project – family members, friends, colleagues – chip in and help you out. A little like when you were doing a sponsored walk as a kid. In the mid term, there is the slow organic progress as new people wander across your project. There are the odd upward blips, and one in particular that we can attribute to our own Max Maxfield when he promoted the project on his blog. (Max has also run his own successful Kickstarter recently.) Things heat up in the final hours, as Kickstarter promotes the project in an 'Ending Soon!' category, which meant that pledges come in right up to the final seconds.

Projects that near their completion date (especially ones that have already past their funding level) attract interest from the technical media, and there are several websites which have been set up to simply re-broadcast the details of your project automatically. It's a cheap and easy way to create content for websites, and provides valuable further promotion of your project.

Rules, rules, rules

Surprisingly, Kickstarter is only open to creators who are residents of UK, USA, Canada, Netherlands, Australia or New Zealand. Even now, six months after starting a Kickstarter project we still have no idea why this is the case. There are strict rules on what projects may and may not be submitted (no weapons, for example) and until recently an odd rule (which we fell foul of) was that you are 'not permitted to offer multiples of rewards' – but everyone worked around this rule, by offering cleverly worded rewards. Kickstarter has now backed down on this and you may offer multiple quantities of a reward, ideal for hardware projects.

A creator is free to cancel a project at any time, but you cannot stop a project once it has reached its funding level – you have to keep it going till the end if you want to receive the funds.

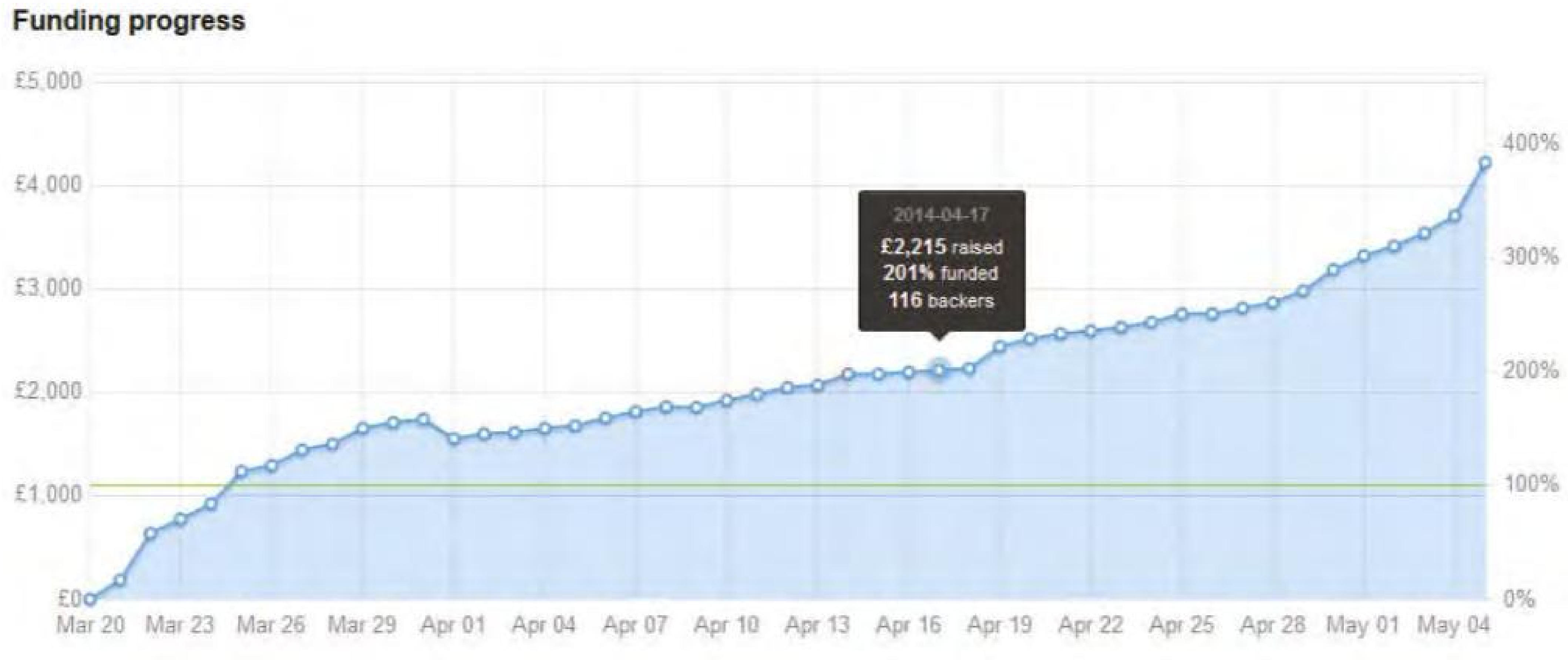


Fig.3. Graph of pledges over time

Project launch

Kickstarter makes creating the project page a breeze, but there is one requirement that made our blood run cold – the project video. Now there are some very slick project videos, and those are great if you have a few thousand pounds spare to spend on a graphic artist and video production company. For the rest of us, it's a HandyCam, AutoCue software and a huge dose of courage. Our video took five attempts, with the words sounding more and more insincere with each recording. Despite all efforts, the effect is still like a rabbit looking into headlights. The website reports that only 39% of people who watched the video played it all the way through. We weren't one of them!

Kickstarter used to require (and no longer do) that a project be vetted before approved for launch, and this could take up to two weeks. So it came as a surprise one Friday evening when the 'You're good to go!' email arrived from the Kickstarter team a week early. It was 9pm, and in our excitement we launched the project immediately, spewing out promotional emails, blog posts, texts and instant messages. There was a wave of responses which kept us busy until 2am, continuing through the following day. Each pledge placed triggers an email message to the project creator and each morning we woke and excitedly reviewed the overnight tally. It was an incredibly exciting time, wondering just how popular this project was going to be, organising manufacturing partners and exchanging emails with people from all over the world (we shipped to 38 countries in the end). After a week, things started to quieten down, with Friday evenings and the weekend appearing to be the more popular times for pledges. Presumably, that's the time when most people are free to access the Internet.

Promoting your project

Having a regular column in a magazine helped enormously with promoting the project, both in terms of getting the word around, and direct interest in purchasing boards. It was still essential to provide regular updates, however, and in the 40 days that the project ran for we posted 15 updates, some of them video blogs. We spoke about the progress securing manufacturing, ideas for use of the board and introduced new pledge levels. Feedback from people helped 'tweak' the design.

There is a strong correlation between posting updates about your project and getting increased support. We did a very simple update one evening, showing the new prototype board, and immediately someone increased their pledge to one of the more expensive options – presumably as our feedback was demonstrating the project was real, and not a scam or badly planned and unachievable. Several others followed suit in the following hours. We also added further pledge options (imaginative methods offering multiple boards) and those were quickly taken up.

Offering 'Early Bird' pledges, where people get a prototype earlier on, increases the interest and carries something of a premium. It also helps you test the manufacturing processes. You can see our 'Early Bird' products ready for shipping in Fig.4.

It's important to keep the pledge options simple, and to focus on the objective – you are seeking funding to make the project *possible*, not simply setting up shop. If you ask for 100,000 pounds to make a PCB with a microcontroller on it, you are not going to be successful. Ask for a few thousand pounds so you can order in bulk, and you might have a chance. Plus, once successfully funded, you attract further support from people who now know your project will happen. It pays to keep things simple.

Delivering

Despite all the preparation and foresight, the real work started once the funds arrived. Because the volumes

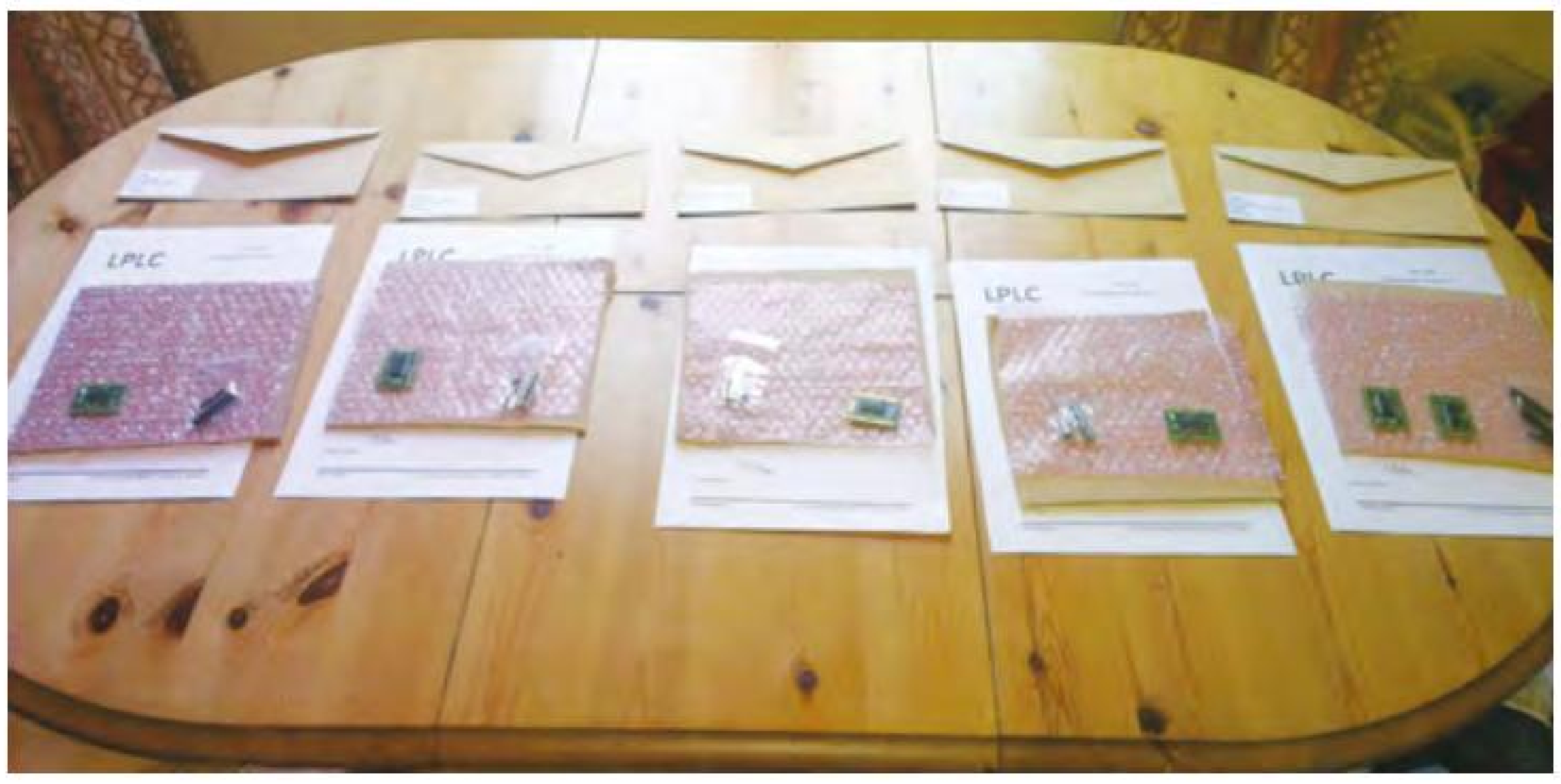


Fig.4. Early Bird boards ready to go

Fig.5. All done, time to ship

were not large, assembly and packaging was done manually – it took a full weekend, over 25 hours in total. At the end, all we had to show for the design, prototyping, video creation, label sticking and a thousand other tasks was a neat but heavy post bag shown in Fig.5, filled with over 400 PCBs.

Conclusion

To answer the obvious and crude question 'did you make any money?', the answer is 'Yes, but we would have earned more delivering newspapers.' To the question 'would you do it again' the answer is 'Yes!', because it was enormous fun and a huge learning experience. What we have learnt will help make the next project be more efficiently executed, and the project after that one might actually be profitable. The project after that – who knows, perhaps Facebook will buy it for a couple of billion USD. If they do, we might write another article!

It's also been hugely rewarding seeing people derive pleasure from something you have created, and at the end of the day, we have come full circle back to *Pic n' Mix* – giving pleasure to others.

We will leave you with a link to a YouTube video showing off the board (and the owners!) capabilities.

www.youtube.com/watch?v=MjoW6 gEb1CY

Not all of Mike's technology tinkering and discussion makes it to print. You can follow the rest of it on Twitter at @MikeHibbett, and from his blog at ***mjhdesigns.com***

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EPE PIC PROJECTS
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This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers. An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

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The three sections of this CD-ROM cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on circuit design problems – from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered. Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 circuit designs submitted by the readers of *EPE*.

The CD-ROM also contains the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial).

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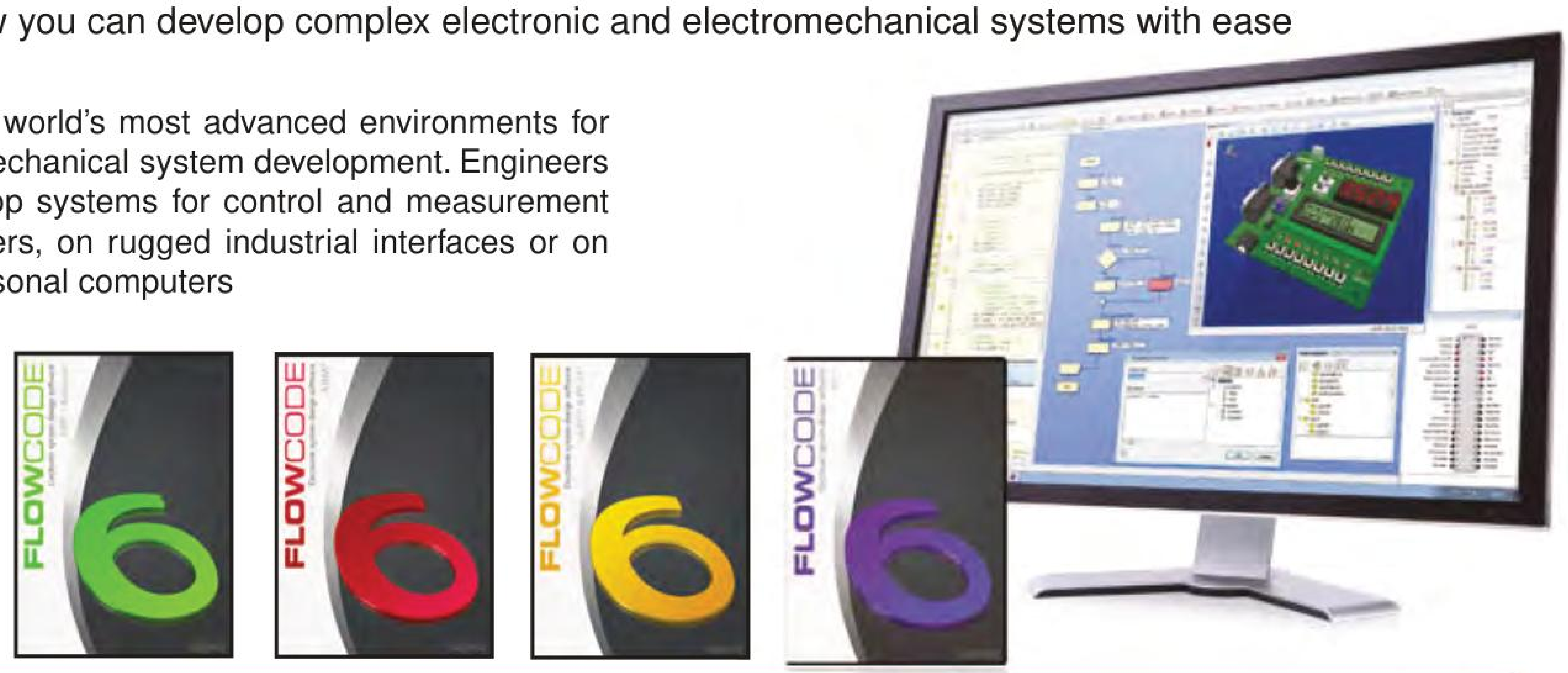

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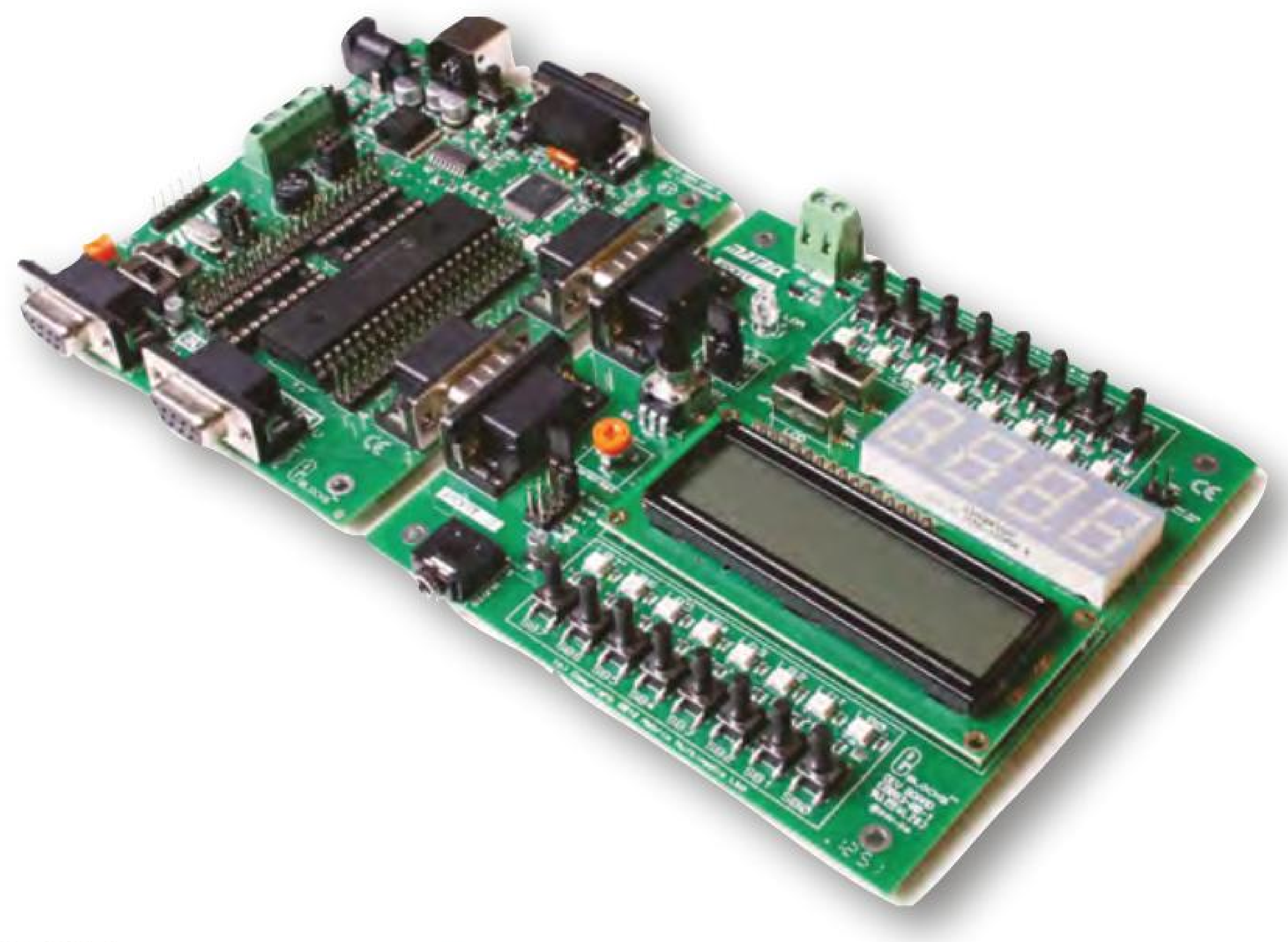


£167 including VAT and postage, supplied with USB cable and free to download programming software

SOFTWARE

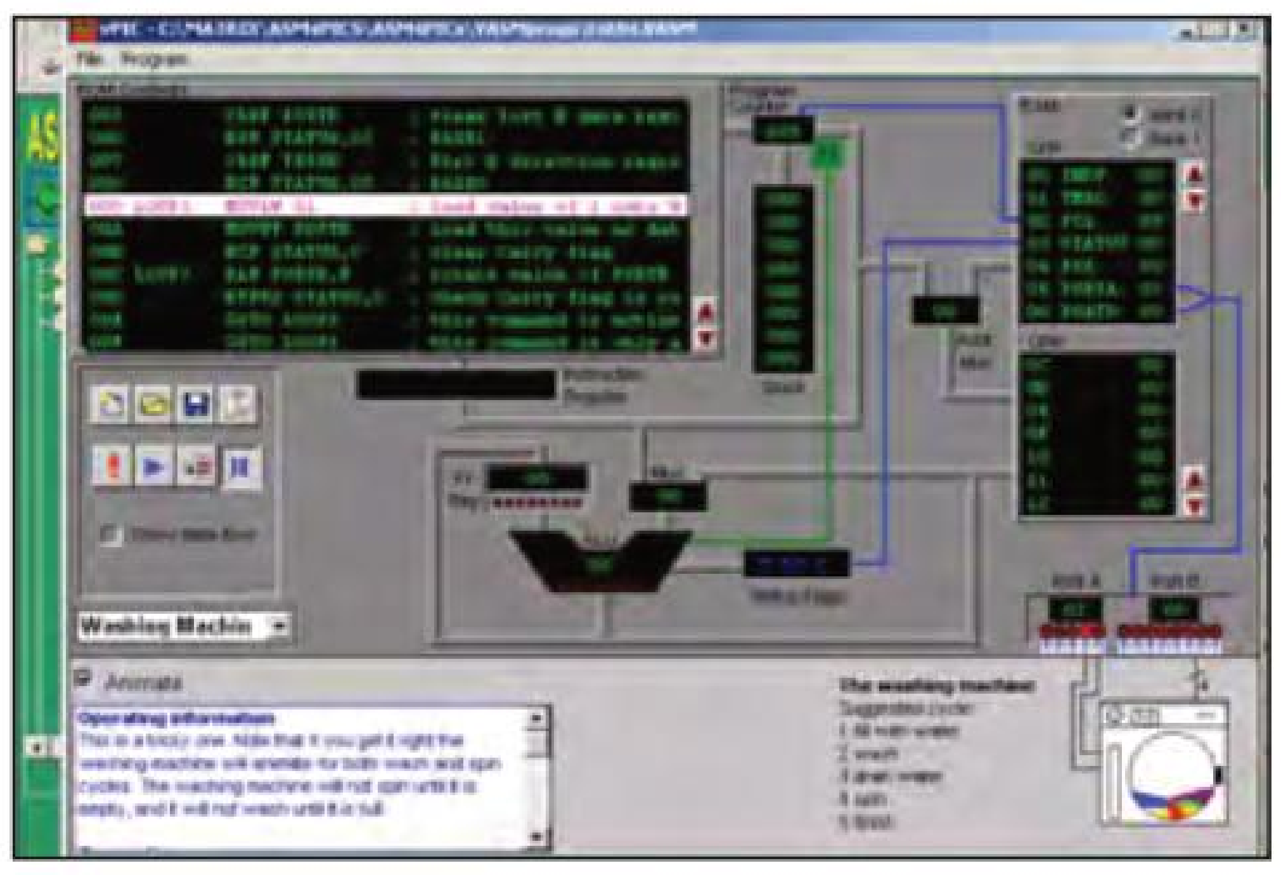
ASSEMBLY FOR PICmicro V5

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.



'C' FOR 16 Series PICmicro Version 5

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

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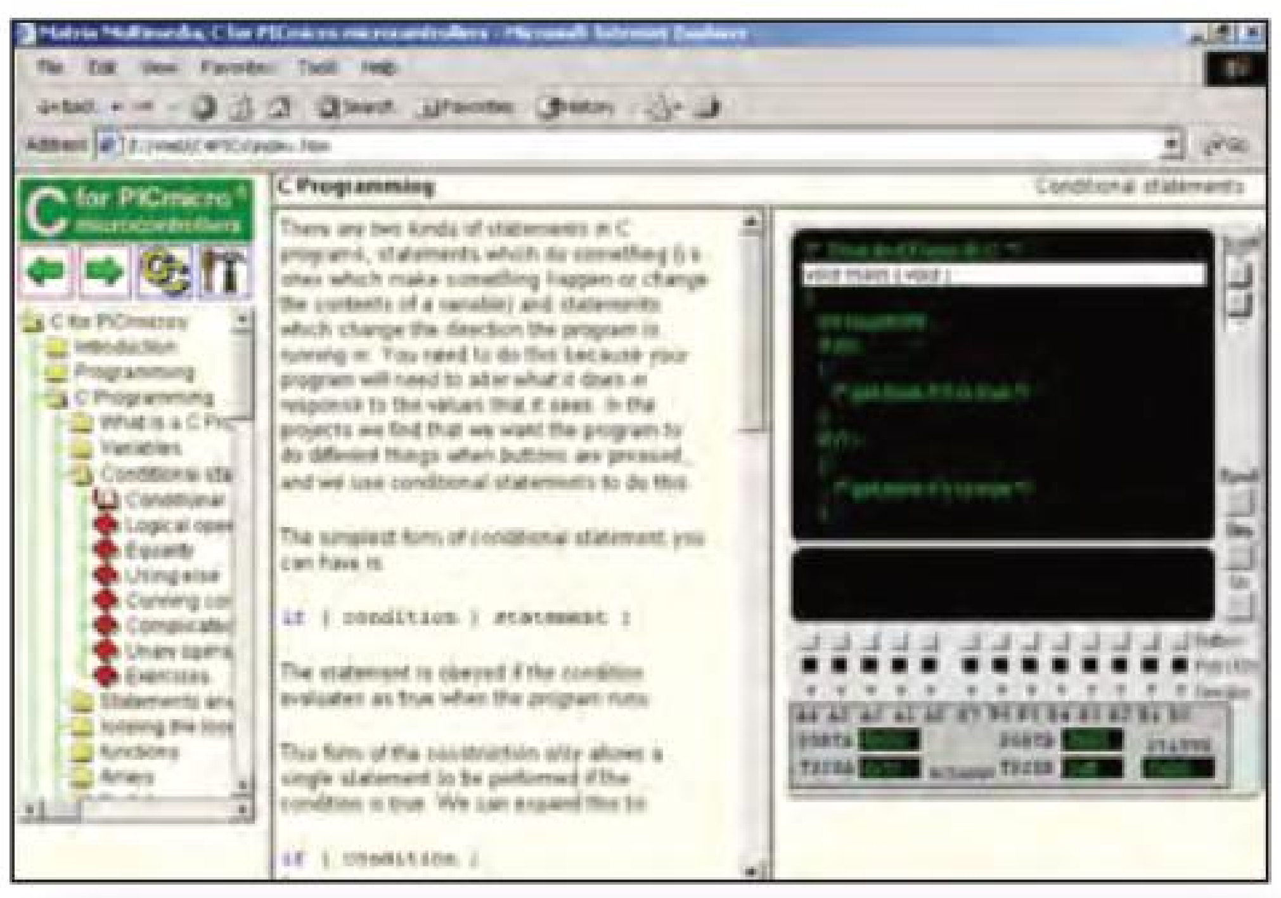
● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V6 (see opposite page)

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
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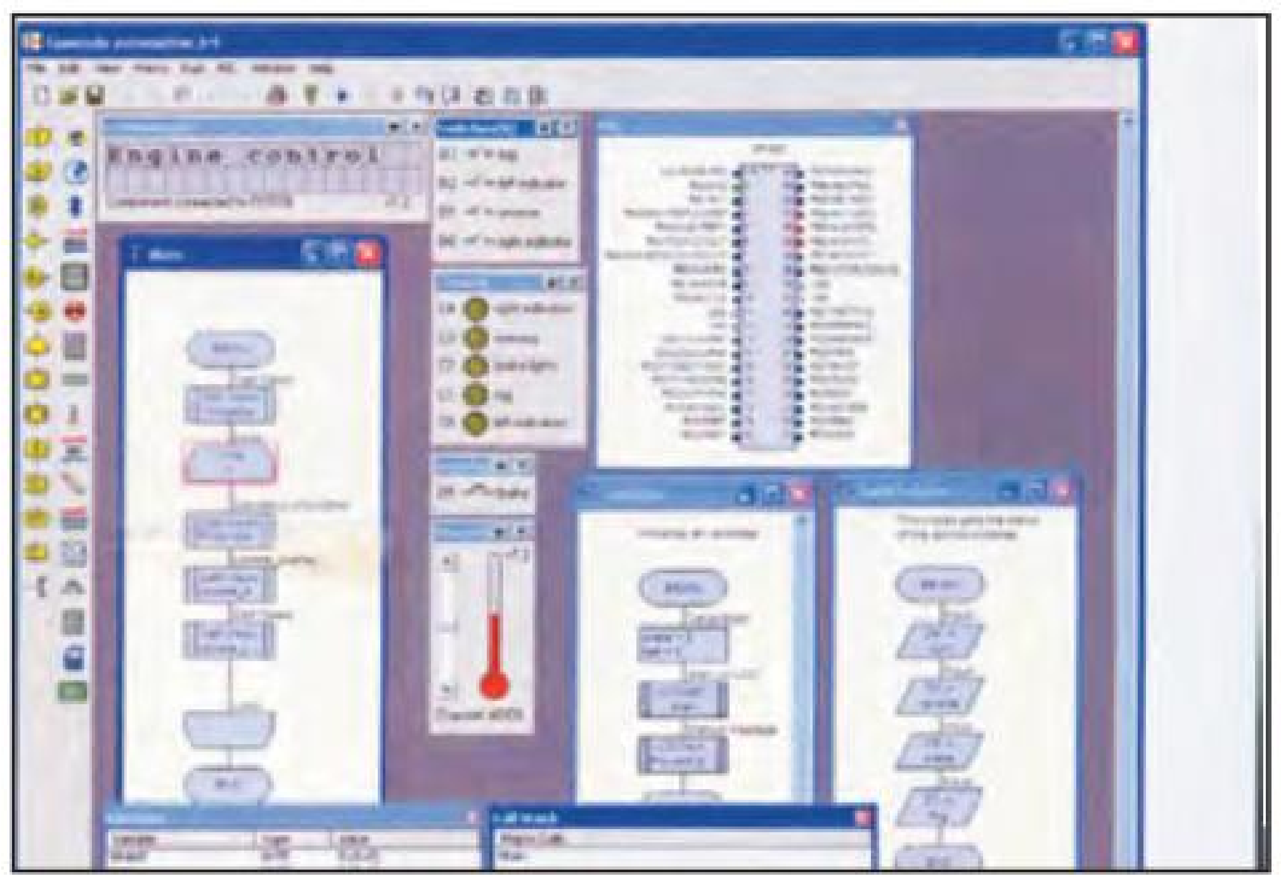
- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

Features include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



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Prices for each of the CD-ROMs above are:

See previous page for Flowcode Hobbyist/Student prices

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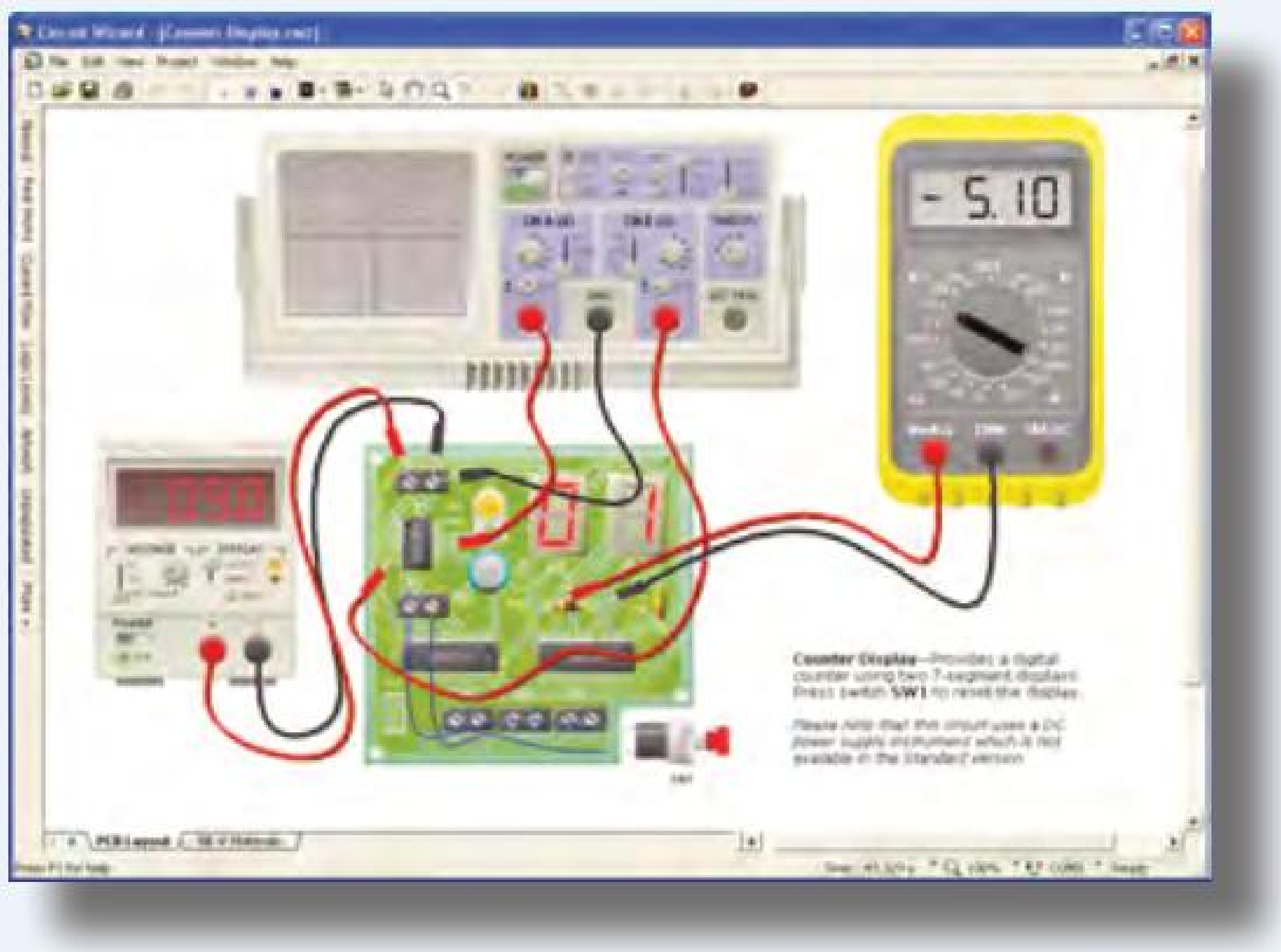

This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

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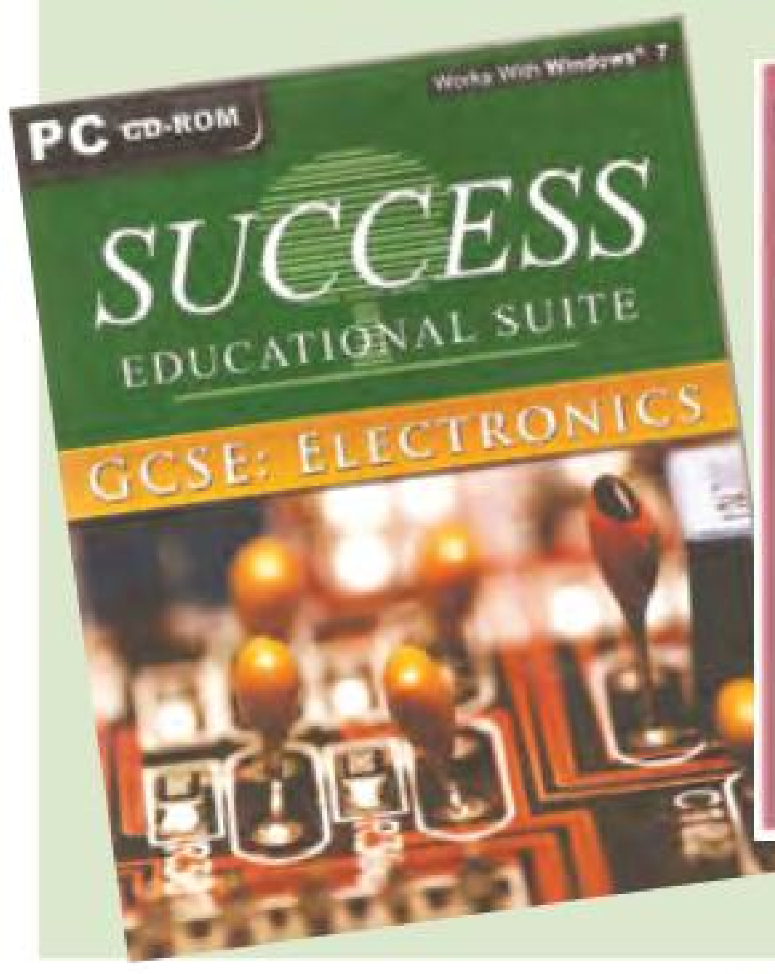

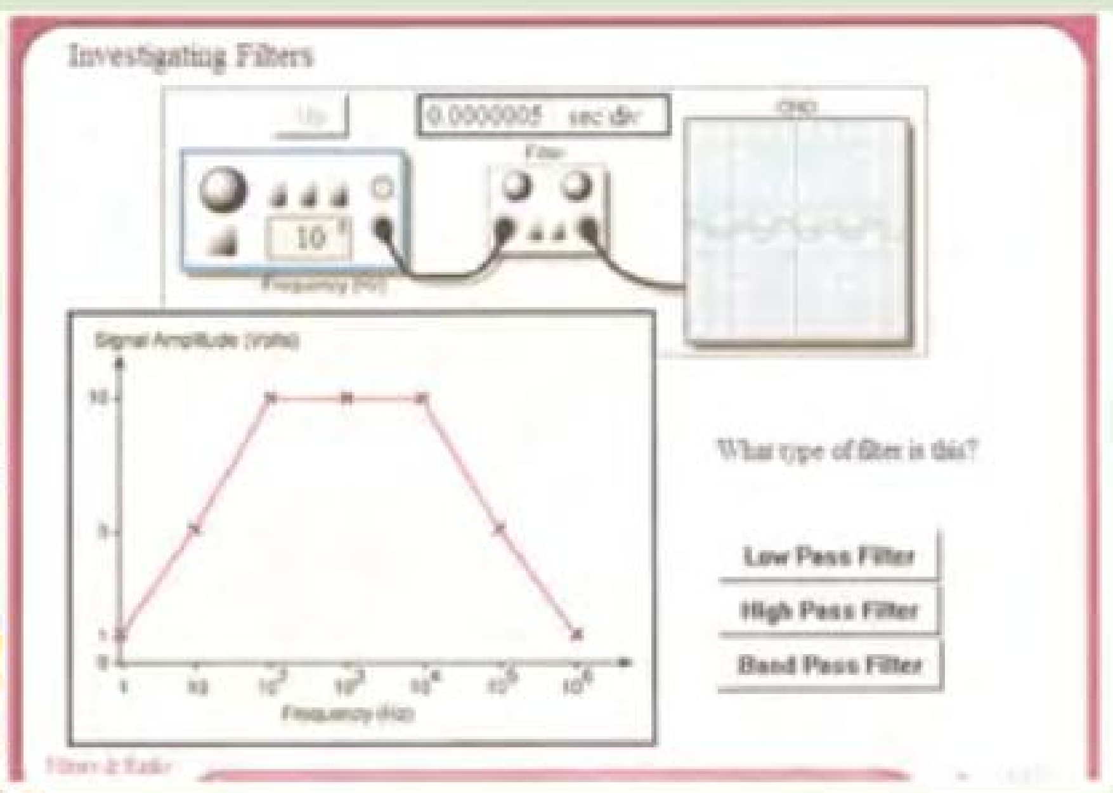

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Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

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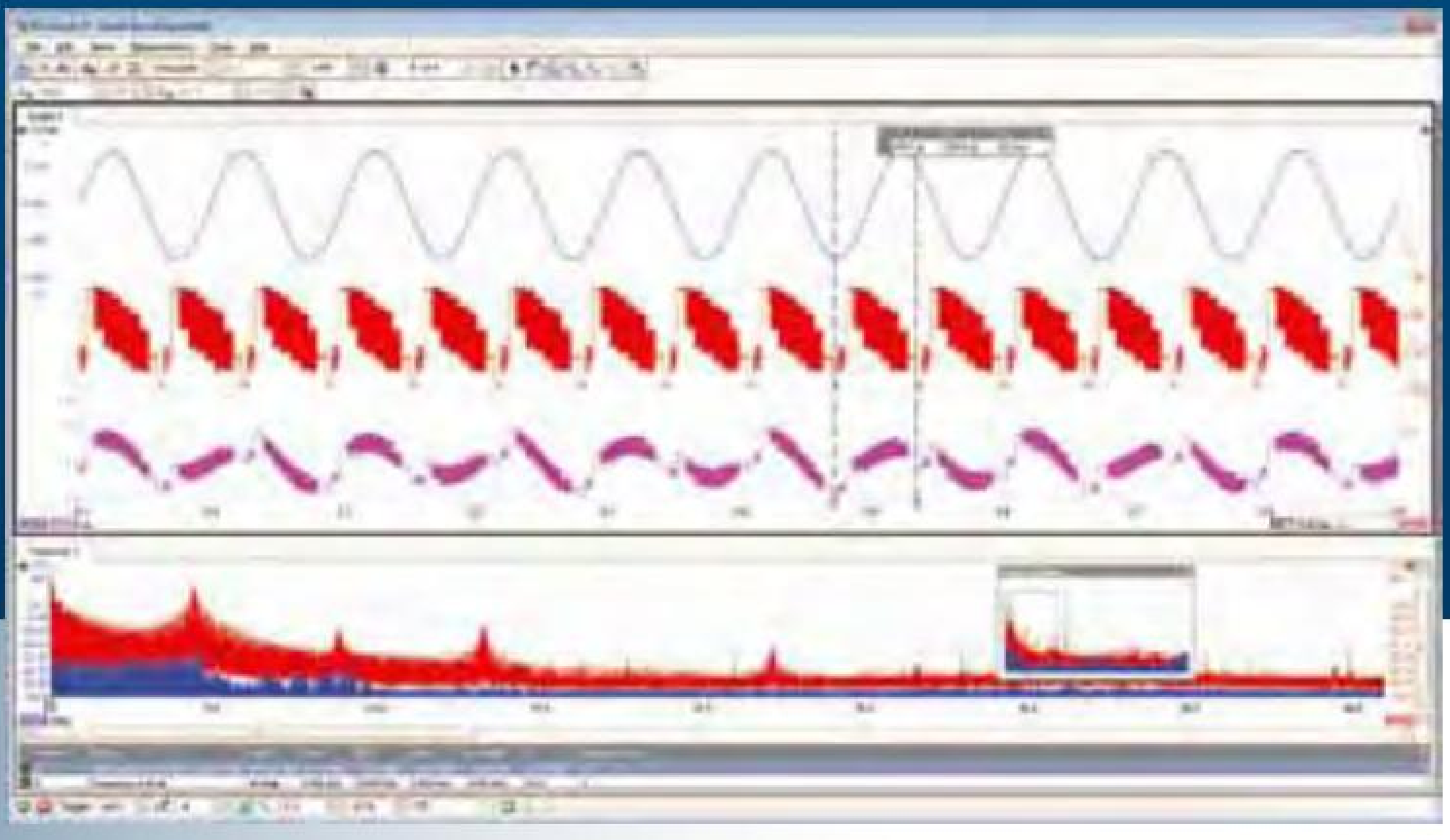

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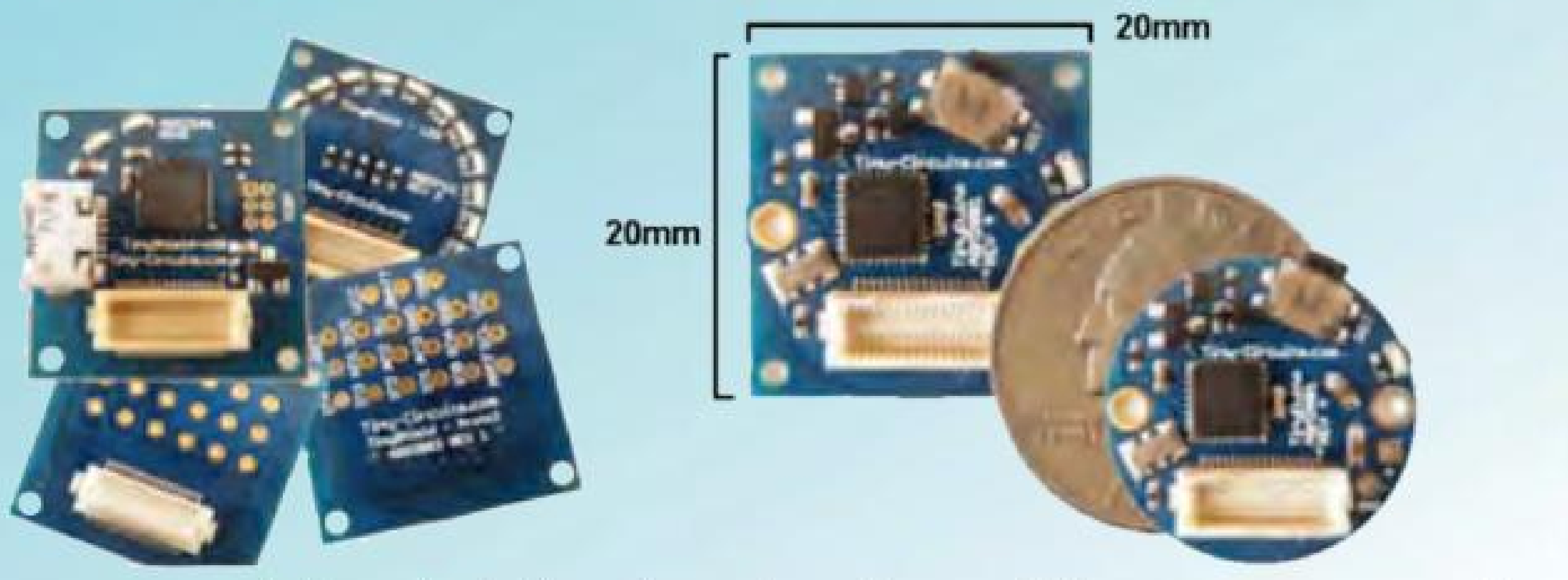

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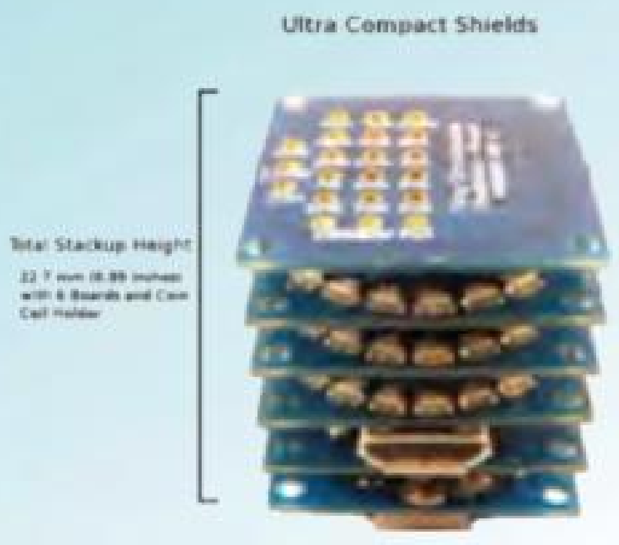

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NET WORK

by Alan Winstanley

A smarter fridge

How often do you rummage through the fridge looking for something that you swear is stashed away, but you can't find it? It's a sandwich disaster – you're fresh out of bacon again! In July's *Net Work*, I mentioned the Amazon Dash, a prototype barcode-capturing or voice-recognition wand that's on trial in the US. It allows consumers to order everyday staples and fresh food direct from Amazon by scanning a code or speaking the product name. The item is then added to an Amazon account for effortless delivery to the door. The replenishment of goods this way obviously needs human intervention because a larder or refrigerator cannot know about changes in stock levels given that no stock movement data is captured directly. We haven't reached the point where barcodes are scanned and goods are checked in or out when someone raids the fridge – not yet anyway. Added to which, it's unlikely anyone wants to control his or her life down to such a minute level.

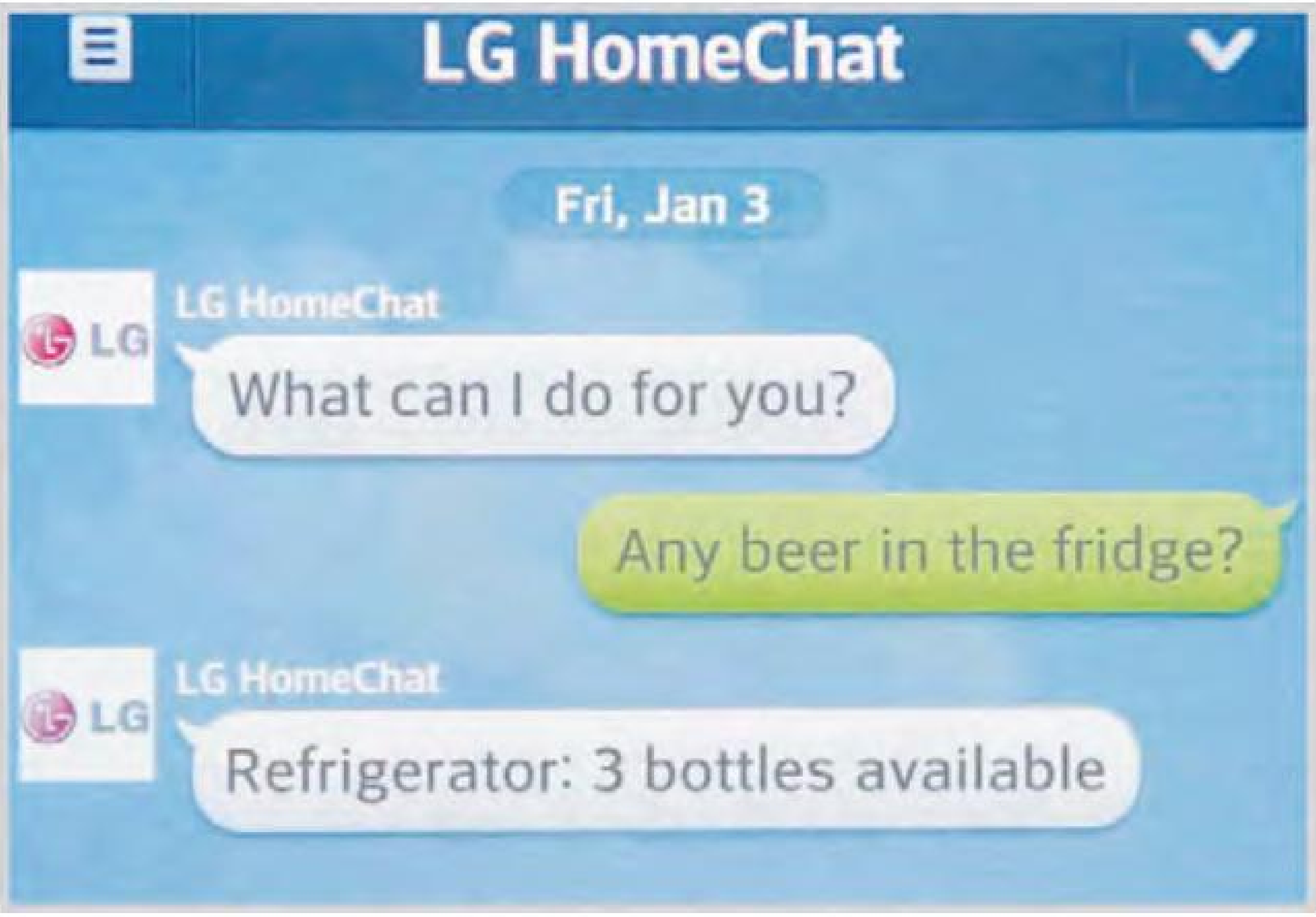
However, if you want to keep an eye on the refrigerator then the next best thing may be round the corner thanks to LG HomeChat, another example of what life may become in a fully-connected world. South Korea's LG has a vision of premium domestic appliances that can 'talk' to users via intelligent mobile messaging, somewhat like a text-messaging system. Thanks to the popular LINE messaging app, LG's smart appliances will be able to understand simple conversation and respond accordingly. A demo video is available at **http://youtu.be/PplAymrv0hA**. The LG Smart Refrigerator claims to be the first appliance of its type to have a wide-angle camera system mounted inside at the top of the main compartment. It is said to detect the opening and closing of the door and captures an image of the refrigerator contents when the door was last opened. The HomeChat messaging system means the fridge could be interrogated in plain English, so the users know what they need to buy when they next visit the grocery store.

Say 'cheese'! – LG's Smart Refrigerator has an internal camera that photographs the contents when the door is opened, to help with re-stocking

Smart, fresh and healthy!

More network-related benefits offered by the LG Smart Refrigerator include Smart Manager, which lets users check the contents without opening the door, and a Freshness Tracker to help maintain food freshness, mindful of expiry dates. A Health Manager app can also suggest recipes and daily or weekly plans to help users meet their individual nutrition goals. The LG SmartLightWave oven is a Wi-Fi microwave that can be messaged on the way home. The app will suggest recipes, and it will set up the oven for cooking: no more twiddling with timers and power level switches. Even the days of the recipe book may be numbered, as the app will offer new recipes when they become available.

So far, LG offers a HomeChat refrigerator, oven and American-style washing machine to its South Korean customers, and they expect to launch in the US and elsewhere further down the road. More of this kind of technology is to be expected from a country that has recently launched 225Mbps broadband on a 4G network.



LG HomeChat

Fri, Jan 3

LG HomeChat

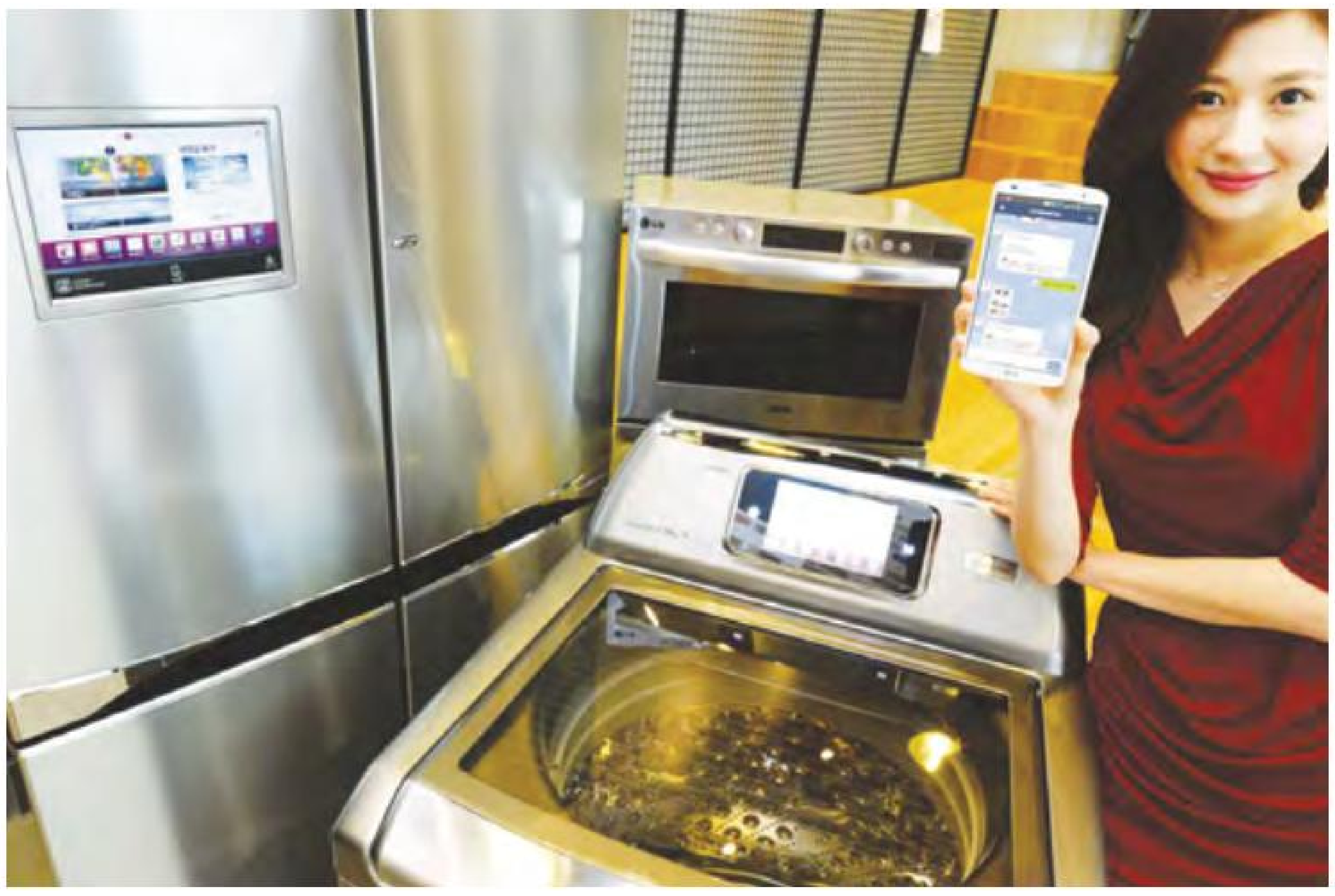
What can I do for you?

Any beer in the fridge?

LG HomeChat

Refrigerator: 3 bottles available

LG HomeChat uses a messenger-style app to communicate intelligently with smart appliances



LG's HomeChat-compatible fridge, microwave and washing machine

A tangled web

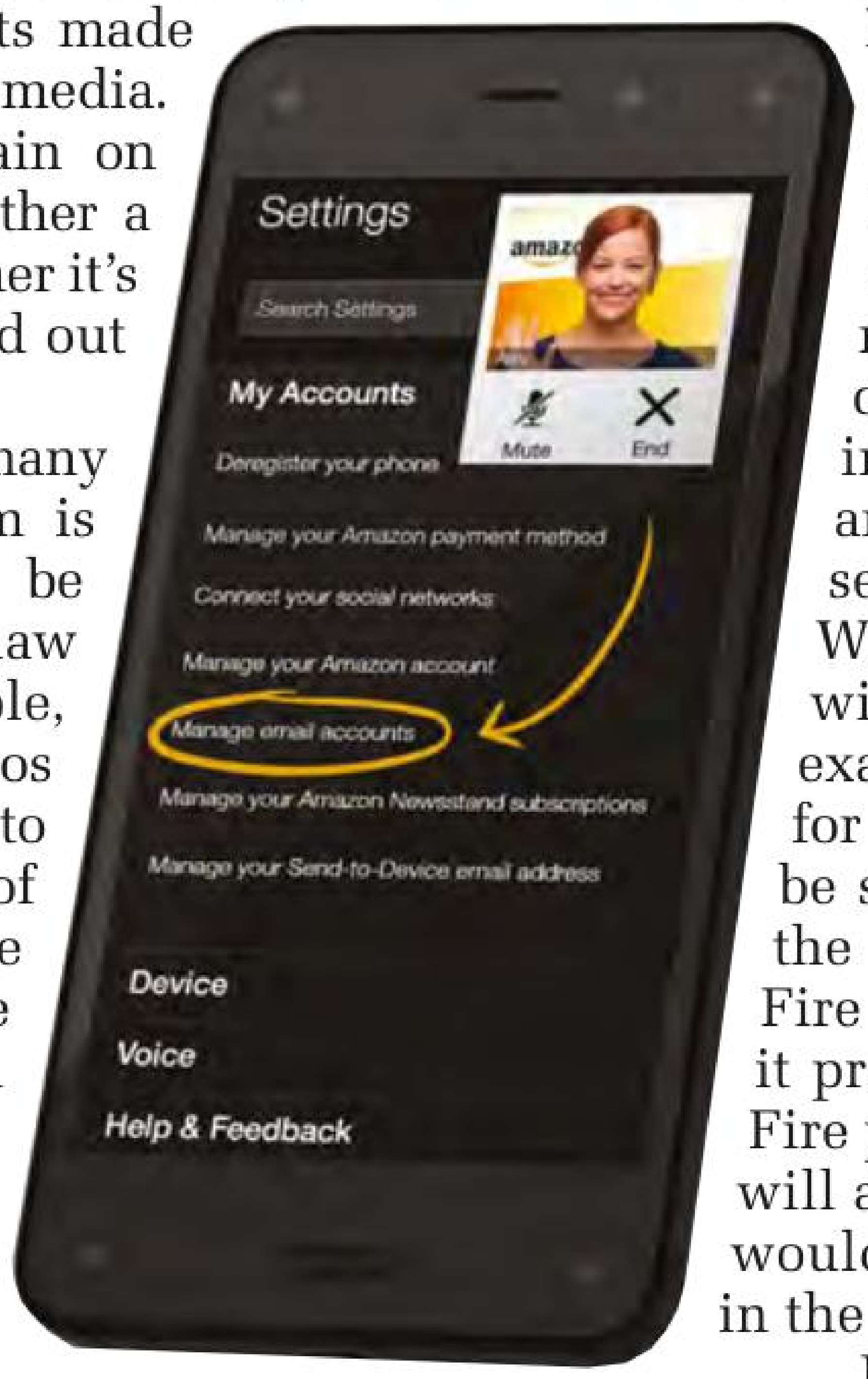
During a visit to a large retail chain's head office, I noticed in the reception area a prominent notice to the workforce regarding their use of social media. It reminded staff not to post defamatory statements (on, for example, Facebook) that could damage the company's reputation or otherwise breach their terms of employment. More recently, a group of steelworkers was sacked for posting disparaging remarks about their employer online, and not even union intervention could save them. The union reported that the workers were unaware of the seriousness of their actions and had learnt a very expensive lesson.

The same could be said of the myriad of Internet users who post thoughtless or malicious reviews about a product, service or supplier without so much as a second thought. After all, it's at arm's length and no-one can do anything about it, right? Everyone has the right to post a personal opinion – provided it does not cost them their job or get them arrested – but posting malicious comments or untruths masquerading as pseudo-facts can cause untold damage to the targets of their vitriol. It can also backfire badly on the poster.

Reputation management

In another example of a malicious review, a woman posted an untrue comment on a Google Local (as it was then known) business website, claiming that a fashion store had treated her so roughly that she nearly 'broke her ankle'. Unfortunately, this untrue 'review' was firmly nailed at No. 1 in Google's ranking system, becoming the first thing that web surfers saw if they googled for the store, and I was asked to deal with it. Believing that such irresponsible remarks can be posted online with impunity is unfortunately a sad sign of the times; nevertheless, after researching certain aspects including usernames and writing styles, I was able to join up some dots and locate the culprit's Facebook page. We backtracked to the store's appointments book and everything fell into place. The customer had supplied an email address, which duly granted us permission to contact her. I can only imagine the poster's feelings when a terse email landed out of the blue in her inbox, and the malicious review disappeared a few minutes later. This type of firefighting work is in regular demand and a new segment of 'online reputation management' has been created as a result.

A local police officer explained to me that the police now receive numerous complaints about Facebook or Twitter abuse, and he wondered how the local constabulary was expected to deal with that. The UK police's professional body, the College of Policing, claims that up to half of a police officer's daily workload may relate to complaints made online, including abuse and threats made on Facebook, Twitter and other social media. The police are struggling with this drain on resources and they have to decide whether a criminal act has been carried out or whether it's a simple playground squabble that spilled out into the (virtual) street.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Online video assistance for Amazon Fire smartphone users is provided by Mayday Help

Existing legislation already covers many forms of online abuse, but one problem is finding the perpetrator, and this may be impossible without intervention from the law enforcement agencies. In a further example, a woman complained that personal videos had been posted online and she wanted to find out who was responsible. Such acts of revenge by jilted partners are illegal in the US, but (currently) not in Britain. In the meantime, without police help the victim would be on her own in trying to find the culprit. Even after locating the website host, which could be anywhere in the world, no ISP will reveal usage data from their server logs without a court order, and if it's located in Russia or China then you can probably forget it. With British lawyers charging £250 ($425) per hour, costs were estimated at £3,000 ($5,100) to both locate the server and, assuming it's in Britain, obtain a court order to reveal the culprit's IP address. More effort would be needed to translate an IP into a physical address, which might need another court order. If the ISP is located overseas, then life becomes more difficult and expensive. Faced with these obstacles, the victim had no hope of proving 'who dunnit.' There is now a call in the UK to change the law to recognise this type of revenge crime.

The matter of a worker's right to post opinions on Facebook works both ways though, as a legal case in 2012 highlighted. A Christian Facebook user posted in his own status page that he did not entirely approve of the subject of gay marriage, and this was duly fed back to his employer, a UK housing authority that demoted him as a result. The High Court decided that he had been entitled to express his own personal views, and it was the recipients of these views – some Facebook 'friends' who reported him to his employer – who had opted into receiving them. His employer was deemed wrong to punish him.

In Germany and some US states, it is already illegal for employers to snoop on personal social media pages this way, but the implications that arise when individuals express a private opinion in public is something that many have yet to come to terms with, as the above-mentioned steelworkers found to their cost.

Amazon Fire phone

Hard on the heels of its successful Fire tablet range, Amazon has entered the mobile phone market with its new Amazon Fire smartphone. Their Android-based phone has a 4.7-inch HD screen and 13MP camera with image stabilisation. Amazon offers free cloud storage for all Amazon content and all photos taken with the Fire phone, with apps downloadable direct from the Amazon App store.

Amazon's forthcoming Fire smartphone is Android-powered and includes Firefly, a powerful image and product recognition function

Amazon's 'Firefly' technology is included – an optical character and image recognition package that will scan and 'read' printed text on posters or business cards, as well as read printed URLs and launch websites. Firefly also promises to recognise music and return information about the artist or album, and do the same with movies and TV episodes, summarising the cast and details of an episode. Built-in Dolby Digital Plus improves music reproduction.

The phone's Firefly function also claims to recognise more than 100 million consumer products, including disks, books and everyday items. By using the Firefly's visual search as a scanner, products can be added to a Wish List or ordered direct from Amazon, which will streamline routine shopping even more. For example, a CD cover or magazine could be scanned for adding to a shopping cart, or a QR code could be scanned the same way. Last, Amazon's Mayday, the live video support service first seen on the Fire tablet, is also provided in the Fire phone and it promises to answer within 15 seconds. Amazon's Fire phone launched in July in the US, but whether it will arrive in the UK is not yet clear. If it does, then I would expect a Christmas 2014 or Easter 2015 launch in the UK.

Next month, I'll discuss more advance in the Internet of Things (IoT) as more networked products arrive on the market. You can email the author at: **alan@epemag.demon.co.uk**

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This book is intended for the new user of the Nexus 7, although much of it will also apply to the Nexus 10. It is easy to understand being written in plain English and avoiding technical jargon wherever possible.

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Even if you are a complete beginner, this book will help you to easily acquire the skills needed to understand and make the most of the Nexus 7.

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KINDLE FIRE HDX EXPLAINED

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WINDOWS 8.1 EXPLAINED

Windows 8.1 is the latest version of Microsoft’s operating system. It is installed on all new Windows Desktop. Laptop and X86 tablet computers and is also available as a free upgrade. Whether you choose to use the touch screen Tile interface or the mouse operated Desktop interface, a good working knowledge of the operating system is essential to get the most from your computer and this book will help you to do just that.

The book applies to Windows 8.1, Windows 8.1 Pro and the vast majority of Windows 8.1 Enterprise. Also parts of the book should be applicable to windows RT 8.1 which is built on the same foundation as Windows 8.1 but is a restricted version designed specifically for ARM tablets.

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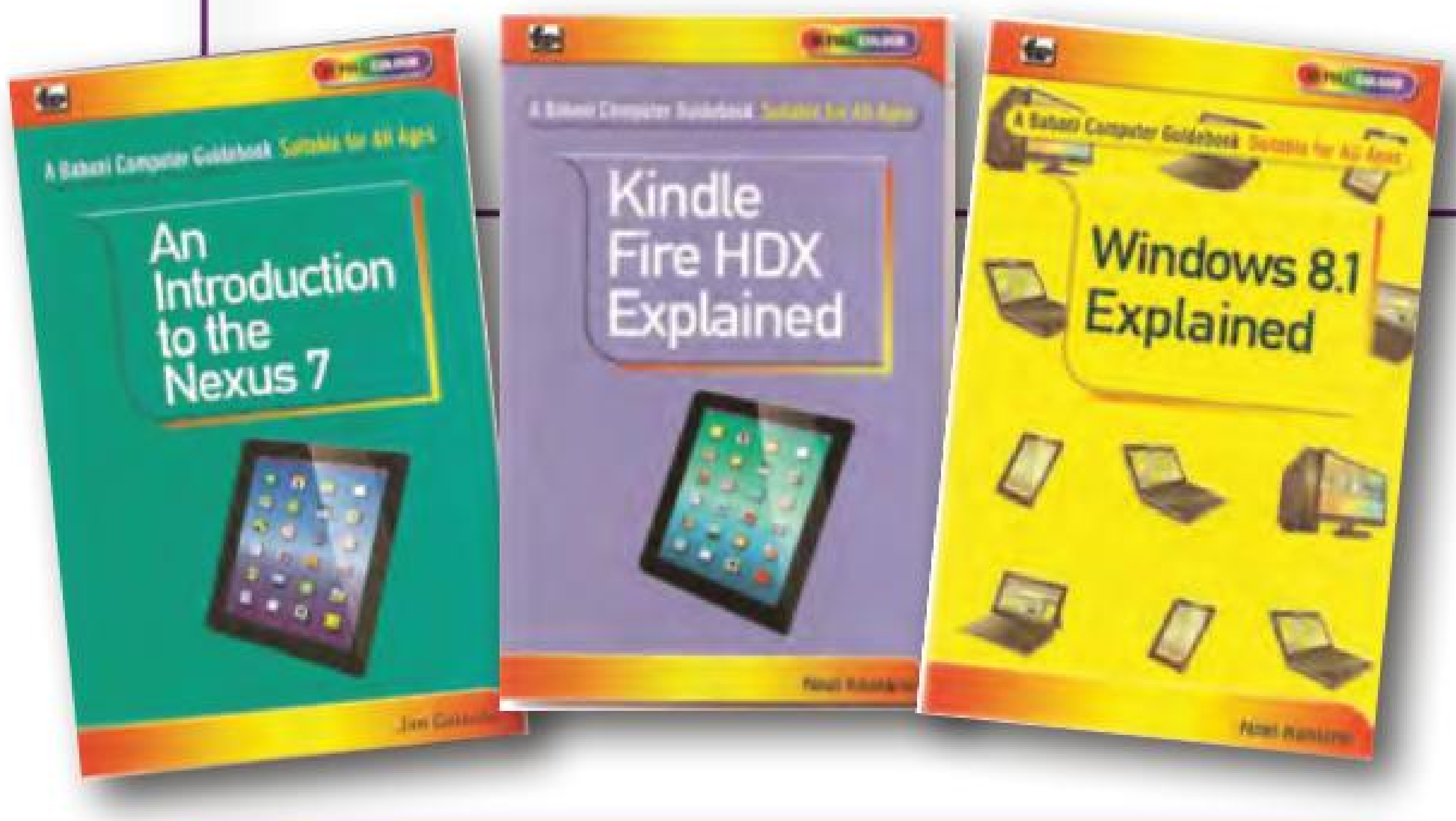
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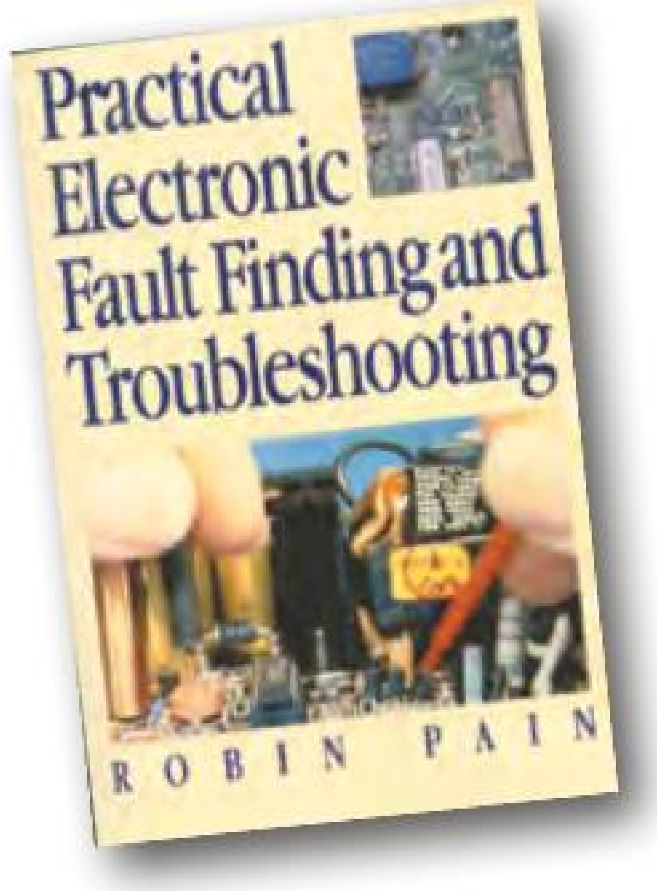

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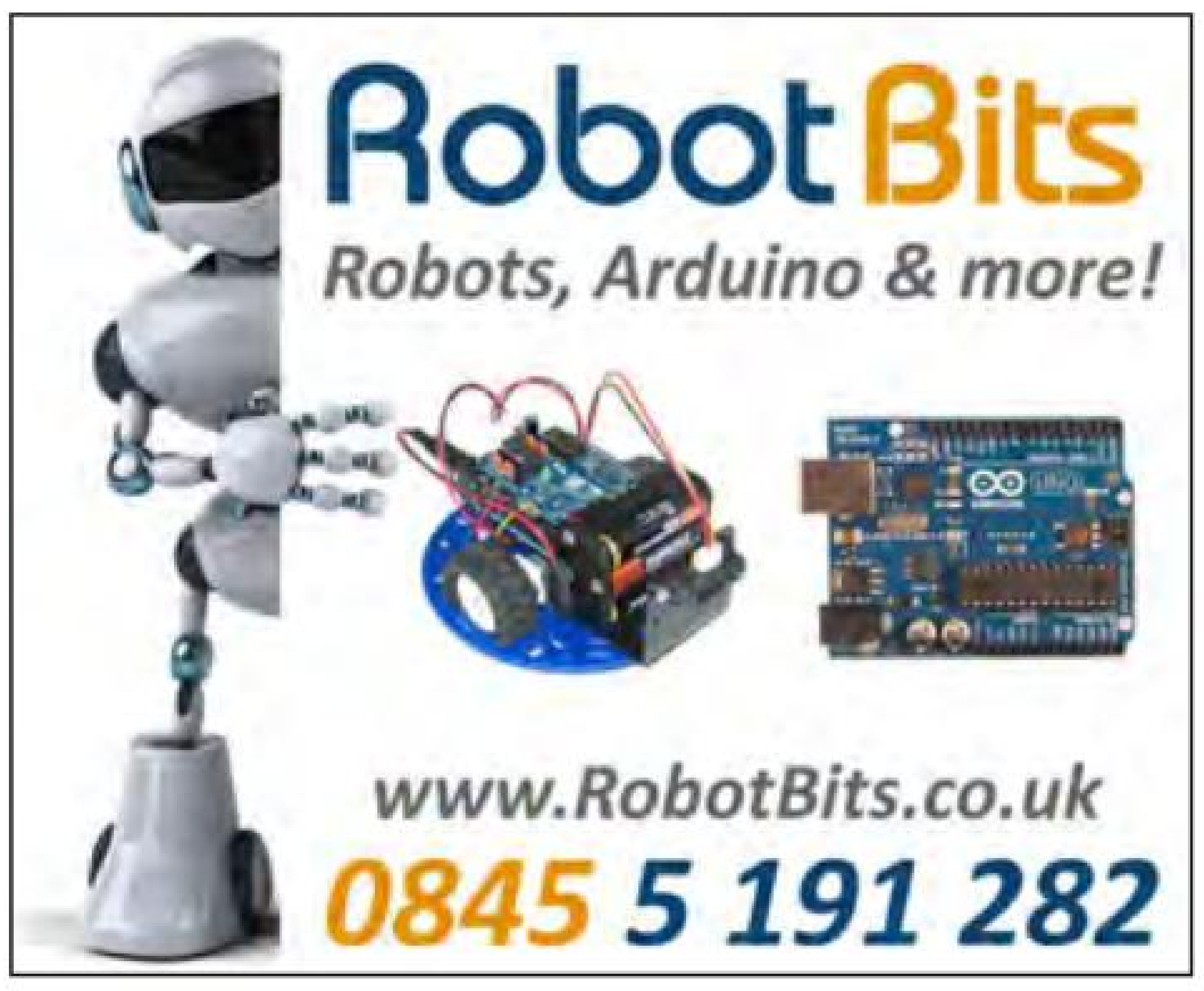
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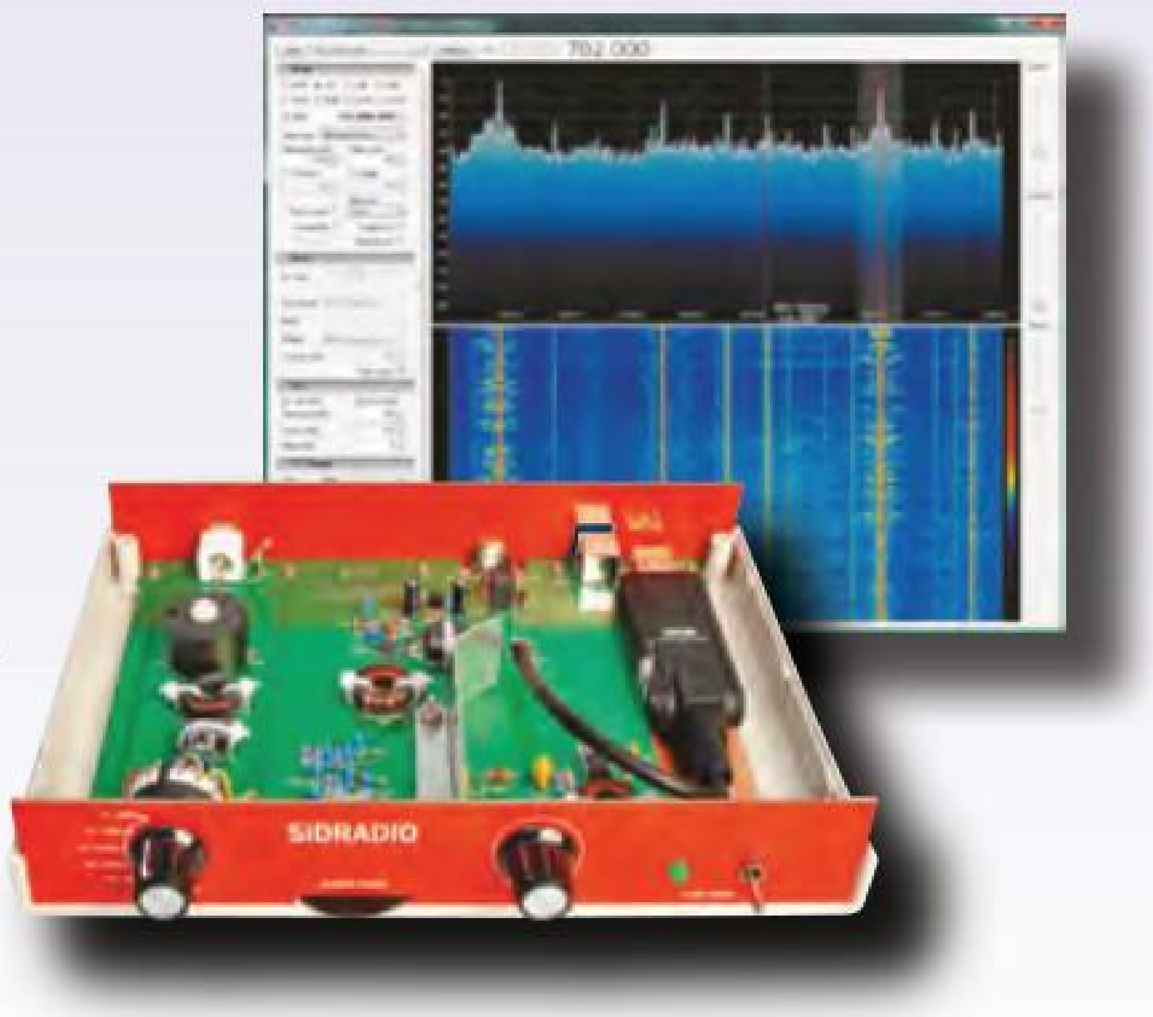
Next Month



SiDRADIO

After last month's *AM Radio* project we jump straight into the 21st century with our *SiDRADIO*, a low-cost communications receiver with coverage from 100kHz to over 2GHz. Using power from your PC via the USB cable, it is a self-contained project, housing a USB DVB-T dongle plus all the circuitry for an Up-Converter and RF preselector.

'Tiny Tim' Stereo Amplifier – Part 1

Most flat panel TVs have mediocre sound quality from their tiny inbuilt downward firing loudspeakers. So how do you get better sound? The short answer is that you need a good quality stereo amplifier with either a Toslink or S/PDIF digital input and some decent speakers. 'Tiny Tim' is our solution, a compact amp with power to around 10W per channel, together with digital inputs.

'Tiny Tim' Horn Loaded Speaker

This low-cost speaker system uses a single 4-inch driver to give surprisingly good bass and treble response. It is quite efficient and only needs a low power amplifier to give excellent sound levels. A perfect partner for the *'Tiny Tim' Stereo Amplifier*.

Build Your Own PCBs – Part 2

Next month, Mike Hibbett explores the language of PCB design, and lays down some of the key concepts before starting on an actual PCB design in our December issue.

OCTOBER '14 ISSUE ON SALE 4 SEPTEMBER 2014

Content may be subject to change

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